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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, Director

REPORT

ON

PROGRESS OF INVESTIGATIONS

OF

MINERAL RESOURCES OF ALASKA

IN

1904

BY

ALFRED H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
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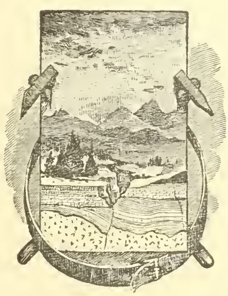

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., January 14, 1905.

SIR: I have the honor to transmit herewith a manuscript entitled "Report on Progress of Investigations of Mineral Resources of Alaska in 1904," and to recommend its publication as a bulletin. The report contains fourteen papers, prepared by ten members of the geologic corps, who have been engaged in Alaskan investigations during the last year.

In this report an attempt has been made to summarize the economic results of last season's field work. Geologic matter has been entirely excluded, except where it has a direct bearing on the subjects under discussion. While such a report can have no permanent value, other than as a record of mining conditions during the year, it is believed that its prompt publication will help the mining industry of Alaska.

Very respectfully,

ALFRED H. BROOKS,
Geologist in Charge Division of Alaskan Mineral Resources.

Hon. CHARLES D. WALCOTT,
Director of United States Geological Survey.

REPORT ON PROGRESS OF INVESTIGATIONS OF MINERAL RESOURCES OF ALASKA IN 1904.

By Alfred H. Brooks and others.

ADMINISTRATIVE REPORT.

By Alfred H. Brooks

INTRODUCTION.

During the last two years the United States Geological Survey has met the demand of the mining public for early publication of economic results by issuing an annual bulletin entitled[a] "Contributions to Economic Geology." Though these volumes have made no attempt to treat exhaustively any of the subjects discussed, and while many of the included papers have been but the barest outlines, they have met a cordial reception from those interested in developing the mineral resources of the country.

Among the many papers in these bulletins were a number devoted to the mineral deposits of Alaska. In view of the rapid extension of the Alaskan work of the Geological Survey and its segregation in a distinct division, it has seemed desirable to issue a separate publication containing the papers summarizing the previous year's work.

It is proposed to present here papers of the same character as those which have in previous years been included in the economic bulletins, namely: (1) preliminary reports on investigations in progress or completed; (2) an account of the less important results which will not find publication elsewhere, and (3) summary statements of the progress of mining developments in various parts of the Territory.

The appropriations for the Alaskan work are specifically made for an investigation of mineral resources. In this fact lies the justification of the policy consistently followed of doing work that promises to be of immediate service to the mining interests, rather than of entering upon minute studies which have for their purpose the ultimate determination of the laws of occurrence of mineral deposits. Furthermore,

[a] Bulls. U. S. Geol. Survey Nos. 213 and 225.

in this field the developments have not yet reached the stage which makes it possible to gather the detailed facts necessary for the exhaustive study of any given area. Of necessity much of the work has been of a preliminary character, but if this fact is specifically stated in the publication of results, intelligent mining men will not give undue weight to the conclusions presented. The attempt has been made to cover the whole mining field, as far as circumstances permitted, and to give the public the immediate benefit of the facts collected.

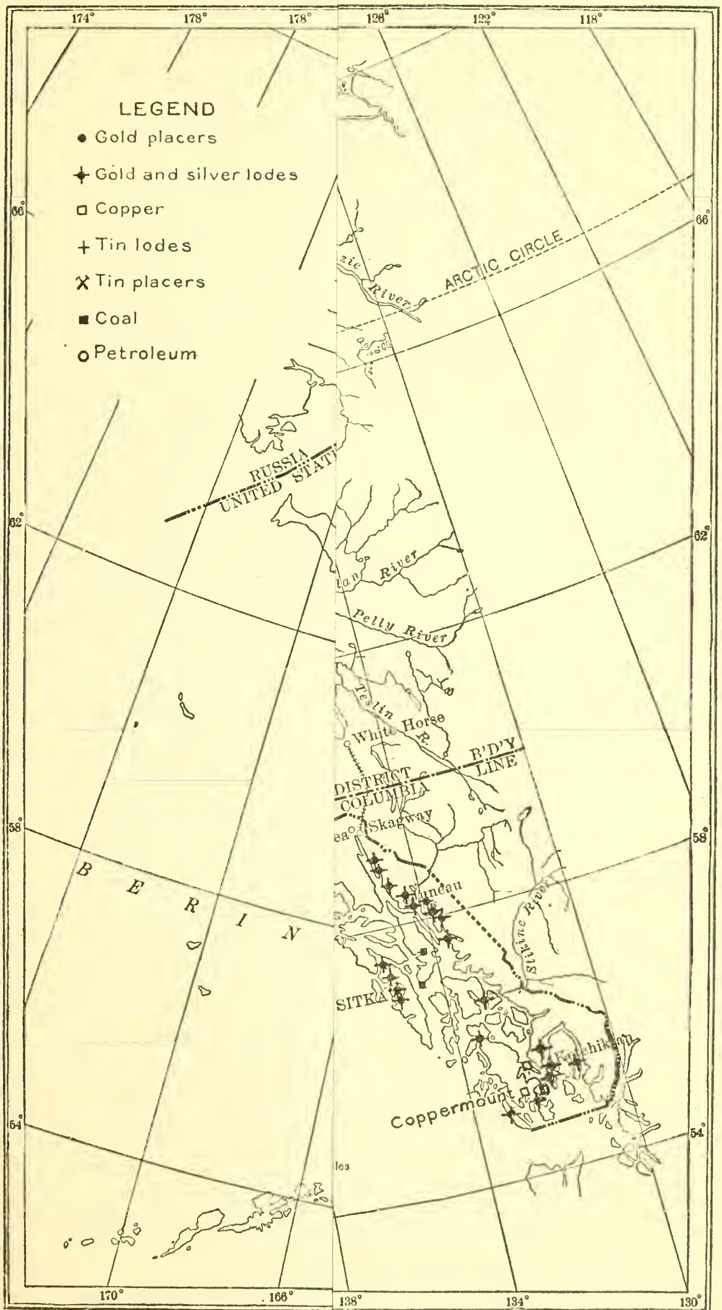
Though it is self-evident that final statements concerning the mineral wealth of a region must be based on a comprehensive knowledge of the geology, it is equally true that many of the facts collected, and even the tentative conclusions reached while the study of the geology is being carried on, may be of very great value to the miner and prospector. If, however, the geologic work stops after the attainment of only such incomplete data and conclusions, its value is soon lost, for the knowledge obtained by the miner during the progress of developments will soon be more complete and reliable than than of the geologist. Reconnaissance investigations must therefore be supplemented by detailed surveys, as fast as warranted by the mining developments.

In Alaska the exploitation of ore bodies has not progressed far, and for the present in most of the mining districts general investigations would appear to best fulfill the purposes for which the appropriation is made.

Much of the attention of the Survey in this field has been devoted to the gold placers, where the conditions of occurrence are so simple that even a hasty examination may lead to important conclusions. As an example, in 1899 a few weeks of field work near Nome indicated that the region had suffered a general uplift, and that very probably old seabeaches and high benches would be found which might contain workable placers. The probable location of such deposits was indicated before any excavation had been made in this type of deposits. Subsequent developments showed that these conclusions, though based on very incomplete data, were correct, for the ancient seabeach and high-bench placers near Nome have since yielded millions of dollars in gold.

Much the larger part of this report will treat of the placer mines, because they are at present the largest wealth producers, and more attention has been given to their investigation by this division. An attempt has been made, however, to summarize the general developments in mining for the year 1904, so far as data are available. If this volume meets with the approval of the mining public an annual bulletin will be issued.

It is a matter of regret that the plan of prompt publication has made it necessary to limit the illustrations to a few outline maps. The important reports here abstracted will, however, be published in more complete form, with all necessary illustrations.


LEGEND
Gold placers
Gold and silver lodes
Copper
Tin lodes
Tin placers
Coal
Petroleum
ARCTIC CIRCLE
RUSSIA
UNITED STAT
Pelly River
Teslin R.
White Horse
B'D'Y LINE
DISTRICT
COLUMBIA
Skagway
Juneau
Stikine River
SITKA
Coppermount
B E R I N
174°
178°
128°
122°
118°
170°
166°
138°
134°
130°
66°
62°
58°
54°

MAP OF ALASKA, SHOWING MINERAL DEPOSITS SO FAR AS KNOWN.

The authorship of this bulletin is composite, for all the geologists of the Alaskan division have made contributions, and each paper will be found credited to its writer. Mr. Cleveland Abbe, jr., has rendered valuable aid in the preparation of the various contributions for publication.

PROGRESS OF INVESTIGATIONS.

Nine parties were dispatched to Alaska during the summer of 1904; of these five were engaged in geologic investigations, two in topographic surveys, one was a combined geologic and topographic party, and one studied the methods and costs of placer mining. As several of the expeditions were subdivided after reaching the field, there were in all fourteen parties engaged in these surveys during most of the summer.

The geologic work included a reconnaissance of parts of southeastern Alaska, a study of the gold, coal, and oil fields of the Cook Inlet region, a continuation of the investigation of the Fairbanks and Rampart districts, a survey of the Cape Lisburne coal field, and a continuation of the work in the Seward Peninsula. Topographic reconnaissance surveys (scale 1:250,000) were made over about 4,000 square miles in the Yukon-Tanana region and about 1,500 square miles in the Cook Inlet placer district, and a detailed map (scale 1:45,000) was made of about 600 square miles near Nome. A special study of methods and costs of placer mining was made in the Juneau, Eagle, and Birch Creek regions and in the Seward Peninsula, and an examination of some of the Canadian placer districts was made for comparative purposes.

General.—Mr. C. W. Purington, accompanied by Mr. Sidney Paige, spent some three months in the study of placer mining methods, as already outlined. A part of his results are presented in this bulletin, and his final report[a] is almost completed. This is the first attempt that has ever been made at a systematic investigation of this subject in this northern field, and it is believed that the results will be of value to those engaged in exploiting Alaskan placers.

The writer's time has been largely given to administrative duties and to the preparation of a summary of existing knowledge of the geology and geography of Alaska, which has been submitted for publication. A brief visit was made to some of the Alaskan placer camps during the summer, and special attention was given to collecting data for the summary of mining developments which follows. Much of the matter, however, contained in this summary should be credited to the men who have been making detailed examinations of the placer districts.

Southeastern Alaska.—Mr. Fred E. Wright, assisted by Mr. C. W. Wright, continued the geologic reconnaissance of southeastern Alaska

[a] Bulletin No. 263.

begun by Mr. A. C. Spencer the previous season. The mineral deposits of Sitka, of Admiralty Island, and of a belt of the mainland between Sumdum and Behm Canal were examined and a supplementary study of some of the principal ore bodies of the Ketchikan district, previously reported on by Mr. Alfred H. Brooks, was also made. An outline of the economic results is here presented; the details will be given in later publications.

Mr. Spencer's report on the Juneau district, based on the field work of 1903, will soon be submitted for publication and will include an account of the geology and resources of Admiralty Island by Mr. C. W. Wright. The part of the Juneau report dealing with the Treadwell deposits forms a section of this bulletin.

Controller Bay region.—Mr. George C. Martin made a supplementary examination of the coal and oil fields of this district. His complete report[a] is now in press, and only a summary appears here.

Copper River region.—No surveys have been made in the Copper River basin since 1902. The final results of the latter investigations are now ready for publication.[b]

Turnagain Arm region.—Mr. F. H. Moffit completed a reconnaissance survey of the gold placer fields tributary to Turnagain Arm. An outline of his report is included in this bulletin. Mr. E. G. Hamilton, who accompanied him as topographer, made reconnaissance surveys of the same area.

Kachemak Bay coal field.—Mr. R. W. Stone, under the direction of Mr. George C. Martin, made an examination of the coal fields tributary to Kachemak Bay. The results of his work are embodied in his account of the coal of southwestern Alaska in this bulletin. The more complete report, with maps and photographs, will be submitted later.

Southwestern Alaska.—Mr. George C. Martin, aided by Mr. R. W. Stone, continued his geologic work of the previous year along the west shore of Cook Inlet. He was fortunate in having the cooperation of Mr. T. W. Stanton, who spent the season in collecting fossils and studying the stratigraphy of this region. Mr. Martin's results are not yet submitted, but his observations on the oil region are given on another page.

Seward Peninsula.—Mr. T. Gerdine, with the aid of Mr. R. B. Oliver and Mr. W. R. Hill, completed a detailed topographic map (scale 1:45,000) of the most important gold-producing area near Nome.

Mr. Arthur J. Collier made a supplementary examination of the tin deposits of the York region, an account of which is given on another page of this bulletin.

[a] Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: Bull. U. S. Geol. Survey No. 250.

[b] Mendenhall, W. C., Geology of the central portion of the Copper River basin: Prof. Paper U. S. Geol. Survey No. 41.

Cape Lisburne coal field.—This area was critically examined by Mr. Collier, whose results are briefly outlined on another page. Mr. Collier not only mapped the geology of the coal field, but made a topographic reconnaissance map of the same area.

Yukon-Tanana region.—Mr. L. M. Prindle, aided by Mr. Frank L. Hess, continued the geologic reconnaissance of the region lying between the Yukon and Tanana regions, and their work completes the preliminary mapping of about half this area. The economic work of this party included further studies of the Fairbanks placers and an examination of the placers of the Rampart region. The results of the first are embodied in Mr. Prindle's report on "The Gold Placers of the Fortymile, Birch Creek, and Fairbanks regions,"[a] now in course of publication. An article in this bulletin outlines the economic development in the Rampart region. A fuller report will be published later.

The topographic work in this same region was extended by Mr. D. C. Witherspoon, who, assisted by Mr. G. T. Ford, mapped an area of about 4,000 square miles. There still remains reconnaissance work for about three parties in this district, besides the detailed surveys which will be demanded by the developments in the richer mining districts.

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[a] Bull. U. S. Geol. Survey No. 251.

PLACER MINING IN ALASKA IN 1904.

By Alfred H. Brooks.

INTRODUCTION.

An estimate based on such data as are available previous to the publication of the Director of the Mint's report indicates that the product of the Alaskan gold placers for the last year has been about $6,000,000.

Approximate [a] production of placer gold.

[Based on estimates by Director of Mint.]

1899	$3,000,000
1900	5,900,000
1901	4,800,000
1902	5,500,000
1903	5,750,000
1904 [b]	6,000,000

If these figures are correct there was an increase in 1904 of only $250,000 over 1903. The reason that this increase is not greater is probably to be found in the unfavorable season, which prevented the anticipated increased production of the Seward Peninsula placers, and to the apparent falling off in the output of the Koyukuk district as compared with 1903. These facts, though possibly discouraging to those who are developing the northern fields, should not be interpreted as indicating that the maximum production has been reached. Placer mining in Alaska will continue for many years to come, and, in the opinion of the writer, its annual contribution to the world's wealth will at least double during the next decade.

It is unfortunate that so many of the larger mining enterprises o Alaska should have suffered both from lack of concise knowledge o the conditions of operation and from the inexperience of those t whom the management has been intrusted. At least half of the com panies which have attempted legitimate placer mining in this field o a large scale have ended in dismal failures. The failures are due t many causes, but probably the most common is the omission of careful study, not only of the gold contents of the placers to b

[a] The production of lode mines, which in 1904 was about $3,000,000, is not included in this table.
[b] Based on estimates made by Alfred H. Brooks.

exploited, but also of the conditions of occurrence of the gold and the best methods of its extraction. Many instances have come to the writer's attention where plants, which are dependent on an abundant water supply, have been established without any exact knowledge of the supply available. Steam shovels have been installed without the knowledge that they are not adapted to work in frozen ground unless the ground is thawed. Thousands of dollars have been invested in ditches to hydraulic shallow deposits when the material could be handled more economically by some mechanical means. This is particularly true in the Seward Peninsula, where the successful operation of several ditches has led many to believe that a fortune is assured if a ditch is constructed. It need hardly be stated that Alaska, where the cost of labor and transportation is great and the season short, is an expensive place to gain experience in mining. Corporations could well afford to make more careful choice of managers than in the past, for this is eminently not a field for the hit-or-miss policy occasionally successful in more favored regions.

SEWARD PENINSULA.

INTRODUCTION.

The placers of Seward Peninsula, with their output of probably over $4,500,000, still hold the first rank in gold production of Alaska. This field, embracing an area of about 20,000 square miles, will excel for many years to come, both by reason of the widespread distribution of its alluvial gold and because in methods of exploitation it is far in advance of all other parts of Alaska except the Pacific coastal belt. Improved methods are the result not so much of the good judgment used by mine operators as of rapid development due to the comparative accessibility of the gold-bearing districts to tide water. In spite of this ease of access, the Seward Peninsula miner who has progressed beyond the pick-and-shovel methods has in most cases still to face serious transportation problems. The twenty-odd miles of completed railway help only a few camps, and freightage by wagon during a wet season is sometimes well-nigh impossible.

Three conditions seriously enhance the cost of hydraulic mining in the peninsula: (1) The comparative shallowness of most of the auriferous gravels; (2) the low stream gradients, which entail additional cost in disposing of the tailings, and (3) the frequent scarcity of water. It is evident that the first two conditions are absent in the case of the high-bench gravels near Nome, and the extension of the ditches into the Kigluaik Mountains will to a certain extent alleviate the third condition. A further discussion of these questions by Mr. Purington will be found elsewhere in this bulletin.

WINTER OPERATIONS.

There is a steady increase of underground alluvial mining during the closed season, and the product of the winter of 1903–4 on the peninsula exceeded $1,000,000.

Drifting methods are in many cases the most economical for the exploitation of rich pay streaks which are covered by great thicknesses of gravel. Wages in winter are 50 per cent less than in summer. Near Nome drifting has been used extensively in mining the high-bench gravels, whose thickness varies from 40 to 150 feet. It appears, however, that deposits might often well be hydraulicked if water be available, for their topographic position makes it possible to find dumping ground for the tailings. Underground mining may involve much expense in locating the pay streaks, the horizontal distribution of which is often very irregular. It is, then, an open question whether drifting is the best method of procedure for many of the high-bench placers, for by it only a part of the values are extracted and, the deposits being gutted, the extraction of the gold that is left might be profitable. It is estimated that high-bench deposits near Nome produced over $500,000 during the winter of 1903–4. High benches are known in other localities, but it appears that they have been but little prospected.

The low-lying gravels of the coastal plain near Nome have been spasmodically worked for several years. Among the most successful operations are some winter diggings along an ancient beach deposit which is parallel to the present shore line from the mouth of Hastings Creek westward to Nome. A deposit which appears to be an old stream channel, near the head of Little Creek, was also worked by drifting methods during the past winter. This is not far from a locality where extraordinarily rich gravels were found in October, 1904. A statement was made to the writer, on good authority, that this bonanza yielded 200 pounds of gold in 7 hours when worked with rocker. As was to be expected, within 24 hours the owner of this remarkable deposit had four injunctions served on him by rival claimants. Gravels of this extraordinary richness have been found at only a few localities, and their occurrence has little bearing on the placer region as a whole. Yet it is significant that such a find should be made very close to the locality of the first discovery in the Nome region six years ago.

Next to the Nome district proper the Solomon River region was the most important winter producer, with an estimated output of $200,000. Here both bench and creek claims were worked by drifting methods. The winter dumps of the Ophir Creek and the Inmachuk regions each produced about $100,000. Besides these large producers there were many localities where the drifting operations of the past winter gave an output of a few thousand dollars.

SUMMER OPERATIONS.

The open season of 1904 was very unfavorable for placer mining in the peninsula. There was a great scarcity of water, partly because of the light snowfall during the preceding winter and partly because of the low precipitation in the early summer. Until July 10 more than half the mines were idle, but from the 10th to the 15th there were heavy rains, and by the middle of the month most of the plants were in operation. There continued, however, to be a shortage of water practically throughout the season. Wages remained at $5 a day and board in most of the camps throughout the season.

Summer mining, though limited to little over two months, was very successful, and much dead work in the way of ditch building was accomplished throughout the peninsula.

The construction of ditches has gone on with feverish activity; probably upwards of a hundred miles have been planned or are under construction, and an equal amount is in use.

It is a significant fact that while methods of mining involving ditch building are the favorites, on Anvil Creek the Pioneer Company has successfully introduced the steam shovel for handling gold-bearing gravels, and the Wild Goose Company is stripping the overburden by hydraulic methods and handling the pay gravels by track and incline. Across the divide, on Glacier Creek, the Miocene Company is continuing its hydraulic elevator work, and has one of the best equipped plants in the district. Some work was done on the Hot Air bench close at hand by the "shoveling in" method. On Dexter Creek only one hydraulic plant was at work, but a number of claims were worked by the sluice-box method. Many other creeks were worked in the Nome district, but most of these only in a comparatively small way. Noteworthy are the hydraulic operations on Dorothy Creek, where an elevator was installed near the head of Nome River. On Hickey Creek, in the same region, a little hydraulicking was also done. A ditch has been completed which is to furnish water for mining bench gravels along the east side of Snake Valley, above the mouth of Glacier Creek. Plans have been formulated to bring water from the Kigluaik Mountains by a pipe line 60 miles in length to hydraulic the high benches along the seaward slope of the hills between Newton Gulch and Anvil Creek. Another company proposes to mine the coastal plain or tundra placers by hydraulic methods, presumably with the use of elevators. The Nome Arctic Railway has extended its track about a mile.

There appears to be little of note in regard to the Penny and Cripple Creek regions west of Nome. Operations were continued throughout the season as far as the scarcity of water would permit. Here, too, ditch building is actively going on and planned.

Considerable mining was done on Osborn Creek east of Nome, but no large plants have been installed. A ditch is under construction which will carry water from near the head of Flambeau River to the heavy gravel deposits near the mouth of Hastings Creek. In the Eldorado basin operations appear to have been confined to "shoveling in" on Venetian Creek. The discovery of bench diggings on the creek is of importance.

SOLOMON RIVER REGION.

The Solomon River region has forged ahead more rapidly than any other district during the last two years, though its gold production is not yet so large as that of several other camps. Four ditches on the main river were in operation or practically completed at the close of the last season. Several ditches were in operation on Shovel Creek, a westerly tributary of Solomon River, and surveys have been made for many more. The extensive but rather shallow gravel deposits near the mouth of Solomon River have been thoroughly prospected and found to carry values, and it is reported that plans are under way to mine these with dredges. Heavier gravel beds occur along the rims of the valley as benches. These are known to carry good values, are well located for hydraulic mining, and are the objective point of several ditches. One small and one large dredge were in continuous operation on the main river during the last season.

The Council City and Solomon River Railway was running trains on regular schedule from Dickson, the coastal terminal, to the mouth of Big Hurrah Creek and beyond throughout the season, and at the same time the construction of roadbed continued inland. Before the close of the season trains were run to the East Branch, a substantial bridge was built across Solomon River at this point, and the grading extended for some distance beyond. Sixteen miles of track were reported completed when the winter set in. Construction work has the appearance of greater permanency than is usually the case in the Seward Peninsula. It is to be hoped that the line may be completed at an early date, as it will give access to many placers which can not be worked under present conditions of transportation. It is noteworthy that the Big Hurrah quartz mine continues to make a good showing. Twenty stamps have been installed and a depth of 150 feet reached in the workings. Some other lode deposits of the district appear promising, and augur well for a permanency of mining in this region.

BLUFF REGION.

At Daniels Creek, 20 miles east of Dickson, the Topkok Ditch Company operated its hydraulic plant practically throughout the season. The heavy gravel deposits which are here being exploited lie in such a topographic position as to be more favorable for hydraulic mining

than any other deposits thus far developed in the peninsula. The feasibility of piping frozen gravels where conditions permit a considerable face to be exposed has here received a practical demonstration. The last season witnessed the extension of the ditch so as to secure more water, but the summer was so dry that even then there was not water enough for continuous piping.

CASADEPAGA RIVER.

The developments on Casadepaga River, whose headwaters lie just across the divide from Solomon River, have shown renewed activity, now that the railway is approaching this district. Heavy bench gravels, which are more or less gold bearing, characterize this region. Most of the work so far has been confined to exploiting the placers found in creeks whose valleys intersect these benches, and in which the gold has been reconcentrated by a natural process of sluicing. Nothing but the crude pick-and-shovel methods could be used, because of the comparative inaccessibility of the district. These primitive methods of extraction were only applicable to the reconcentrated placers, and not to the heavy bench gravels. Ditches are proposed for working the latter deposits, and some of them are already under construction. In planning to use hydraulic methods, it should be borne in mind that the benches are not high, and here, as at many other localities, the disposal of the tailings will entail a heavy expense.

COUNCIL REGION.

Ophir Creek is to-day not only the greatest producer on the peninsula, but has the largest reserve of gravels of unknown value. Claims were worked throughout the length of the stream as far as Crooked Creek. The winter work has already been referred to, and the summer developments were along the lines reported last year.[a] Various methods are employed, including hydraulicking benches, hydraulicking creek claims with elevator, "shoveling in," use of derricks, horse scrapers, etc. Some work was done with a dredge along the banks of Niukluk River near the mouth of Ophir Creek. Some lesser mining operations were carried on on Crooked, Ward, and Gold Bottom creeks in this region.

KRUZGAMEPA REGION.

A number of the tributaries of the upper Kruzgamepa River have been found to be gold bearing, but, of these, Iron Creek only has made any considerable production. Some rich stream placers have been exploited on the latter creek, but the operations have been chiefly confined to shoveling methods. With the extension of the railway this district will become more accessible.

[a] Brooks, A. H., Placer gold mining in Alaska, 1903: Bull. U. S. Geol. Survey No. 225, p. 53.

KOUGAROK REGION.

The Kougarok region is rapidly increasing its gold output, though its isolation has made it an expensive camp to work. Several ditches were in operation in 1904, and a number of others were planned and under construction. Harris and Dahl creeks have been the heaviest producers, but several others besides the main Kougarok River have yielded gold in commercial quantities. Attention has repeatedly been called to the heavy bench gravels which are characteristic of the Kougarok Valley. Some of these are known to be gold bearing, and, exploited by proper methods, should become important producers. Drilling on Dahl Creek developed bench gravels to a depth of over 180 feet, thus showing them to extend below present sea level.

PORT CLARENCE PRECINCT.

In the Port Clarence precinct the ditch to Sunset Creek was completed, but little hydraulicking was done. A number of claims were worked in the Bluestone region, but no important developments were made.

FAIRHAVEN PRECINCT.

The northeastern part of the Seward Peninsula, comprising the Kiwalik, Inmachuk, and Buckland placers, is included in the Fairhaven precinct. Here the conditions for rapid development are much less favorable than in other parts of the peninsula. The open season for navigation is somewhat shorter, and supplies for the camp have to be transferred at Nome to shallow-draft steamers which can traverse the shoal water found at the northern margin of the peninsula. In spite of the adverse conditions the region is prosperous. Thanks to a local coal supply found at Chicago Creek, considerable winter mining was done. Very little ditch work has been done in this region, but plans have been laid looking toward an improvement of the present methods of mining.

GOODHOPE PRECINCT.

There has been but little mining in the Goodhope district, which embraces the extreme northern part of the peninsula. Though gold occurs in the beds of a number of the tributaries of Serpentine River, under present conditions it probably can not be extracted at a profit.

KOBUK DISTRICT.

The reports from Kobuk River indicate that there were upward o 100 men prospecting in this region, and many appear to find encour agement in what they have discovered. Whatever may be the poten tial resources, the actual gold output of the placers has probably no

exceeded $10,000 or $15,000. The producing claims are reported to have averaged $10 a day to the man. The last season was a very wet one, and operations are said to have been hampered by high water in the creeks.

YUKON DISTRICT.

Prospectors who maintained their faith in the Tanana-Yukon district during the waves of popular excitement which carried most of the mining population first into the Klondike and then to Nome, bid fair to have some of their hopes realized. A broad belt of metamorphosed rocks stretches westward from the international boundary near Dawson to the Yukon at the Ramparts, and in this belt are many localities which are known to be gold bearing. The general features of the occurrence of gold placers in the various camps of this field are similar, though the local variations are sufficient to bring about differences in mining values. Thus in the Klondike the high-bench gravels or "white channel," as they are called locally, have proved large producers. The high gravels in the Chicken Creek basin of Fortymile have also yielded considerable gold, but those of the Rampart region, up to the present time, have not been found to carry mining values under the present conditions. Fortymile probably has advantage over the Klondike in the water supply, but its placers have thus far proved not nearly so rich. The placers at Fairbanks are far more accessible than those of Fortymile, but are probably at a disadvantage in regard to stream gradients and water supply. At all events, sufficient work has been done in this belt, over an area of probably 20,000 square miles, to show a wide distribution of placer gold. The events of the last two years show that the limit of discovery of rich placers may not by any means have been reached, while the low-grade gravels remain practically neglected.

RAMPART REGION.

The most westerly camps of this belt lie in the so-called Rampart region, and are described in detail by Mr. Prindle on pages 104 to 119 of this bulletin. The most encouraging features, according to Mr. Prindle's statement, are the successful operation of some small hydraulic plants, which has stimulated other similar enterprises, and further discoveries of good pay in the valleys of the the best known creeks. He calls attention to the extensive deposits of high-bench gravels in this field, but so far prospecting has not shown them to contain workable placers.

FAIRBANKS DISTRICT.

One hundred miles to the east of the Rampart region is the new Fairbanks district, whose increase of output from $40,000 in 1903 to probably $400,000 in 1904 has made it the immediate focal point of interest

to the Alaskan mining public. Though this gold was taken from only a few creeks, there are twelve more on which encouraging prospects have been found.[a] These drain an area of approximately 500 square miles, which can be regarded as the gold-bearing district, as defined by present knowledge. What part of this area carries commercial values must be determined by more careful prospecting than has yet been done. All of the creeks are within 25 miles of steamboat navigation on the Tanana, and the construction of the railway now under way will make this camp more accessible than any other of the Yukon region. Mr. Prindle's studies have shown that where excavations have been made the gravels are generally deep and often covered by a heavy overburden of muck. The water supply is not abundant, and hydraulic operations may find in this a serious obstacle. Low stream gradients also offer the usual difficulties in the disposal of tailings. These conditions, as far as they are understood, indicate that mechanical means of handling the gravels will find preference over hydraulic methods, unless further surveys should discover sources of water not now known. Much of the gold mined thus far has been taken out by drifting. Last fall scores of boilers were shipped to Fairbanks, and probably many of these are now in use taking out winter dumps.

The heavy growth of spruce along the larger valley floors yields an ample fuel supply for the present, and the local sawmills have supplied the necessary lumber. In spite of this, lumber was sold on the creeks last year as high as $200 per thousand feet, and the supply will soon become exhausted unless efficient measures are adopted for protecting it against the present reckless waste.

Last summer the Fairbanks district probably contained a population of 4,000 to 5,000, which is far in excess of what the present discoveries and developments could support. Three thousand people, mostly in the town of Fairbanks, are said to have remained through the winter. This town, the headquarters of the precinct, is on a slough of the Tanana, navigable for large steamers only during favorable stages of water. Chena, a rival but much smaller settlement, lies on the main river, nearly 10 miles below. Fairbanks is connected with the producing creeks by telephone and with the outside world by military telegraph. From about the middle of June to the middle of September it can be reached by steamer from Dawson in about seven days. The journey from St. Michael by steamer up the Yukon is a little longer, and the entire route is not open until after July 1. Summer freight rates to the creeks last season were from 10 to 20 cents per pound, while the winter rates were about a quarter of this sum. The following notes were furnished by Mr. Prindle:

The gold-producing creeks in 1903 were Pedro, Cleary, and Fairbanks, together with some of their tributaries. The three main creeks are all small streams, carrying

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[a] Prindle, L. M., The gold placers of Fortymile, Birch Creek, and Fairbanks regions, Alaska: Bull. U. S. Geol. Survey No. 251, p. 85.

ordinarily less than 100 and seldom over 200 inches of water. They flow in open valleys, with a grade of about 100 feet to the mile. The stream gravels are comparatively deep and in most localities frozen throughout the year. The average section shows a layer of muck underlain by barren and pay gravels. The last are mostly quartzite and mica-schist, are rather angular, and are mostly under a foot in diameter. They frequently contain considerable clay in the lower portion, and the proportion of bowlders is small. The thickness of the different layers varies greatly and the maximum total depth, so far as determined by prospect holes, is over 80 feet.

On Pedro Creek the depth to bed rock is 8 to 30 feet, and the alluvium includes muck, barren gravels, and pay dirt. The last is 1 to 4 feet thick, and gold is found in the decomposed bed rock to a depth of 1 to 5 feet. Pay streaks are from 40 to over 200 feet in width. Values vary from 3 to 25 cents to the pan, and much of the ground has probably averaged $1.50 to square foot of bed rock. The largest nugget was valued at $19.

Steam point drifting and open cut are the methods chiefly employed. Boilers up to 30 horsepower are in use. Work is confined mostly to the 3 miles of Pedro Creek between Twin and Gilmore creeks, though some gold has been taken out on Twin Creek. On Gold Stream the gravels are 30 feet or more in depth. It is probable that as conditions improve considerable work will be done in this lower portion of the valley.

On Cleary Creek work has been done from near the head to within 2 miles of the mouth, a distance of about 7 miles. Here the depth to bed rock is 14 to 80 or more feet, and averages over 50 feet. The material is muck, barren gravels, and pay dirt, and the gravels average about 20 feet in thickness.

The pay streak is 1 to 7 feet, and gold is found to a depth of $1\frac{1}{2}$ to 4 feet in the bed rock. The width of pay streak is 35 to 150 feet; so far as determined, it is on the low bench on the west side of the creek above the bend, and on the opposite or north side below the bend. The gold includes, as on the other creeks, a flat variety in pieces up to one-fourth inch or more in diameter, and a coarser variety, of which one nugget was valued at $233. Values in the pay streak average from 2 to 25 cents to the pan, but occasionally are much greater. One pan seen by the writer yielded nearly $5.

Chatham Creek is a small tributary of Cleary Creek. It is only about 1 mile long, but has been a gold producer. The depth to bed rock is 10 to 30 feet. The gold from the head of the creek is very rough.

The drifting method is used on Cleary and Chatham creeks and some open-cut work on Chatham Creek where the depth permits. Some good values have been found above Discovery claim, but this portion of the valley last season was still in the prospecting stage. Most of the production thus far has been from Discovery claim to Claim No. 4, below Discovery, inclusive, and extensive work has been done in this portion of the valley. Boilers up to 20 horsepower were in use and handled from 20 to 50 cubic yards of dirt a day, with a fuel consumption of a cord of wood every 24 hours. The wood cost $10 per cord delivered on claim. Wages were generally $6 a day and board.

Last summer developments were being made to within 2 miles of the Chatanika, and it seems probable that as the conditions of development became more favorable considerable ground will be worked at a profit in this lower portion of the valley of Cleary Creek. It is probable that under the conditions which existed in 1904 gravels could not be worked at a profit for a gold content of less than 3 cents to the pan.

Ditches are built with difficulty, and the cost of production in some cases was increased by the frozen muck and "live water" in the lower gravels.

On Fairbanks Creek there was, in 1904, active work from No. 8, above Discovery, to No. 8, below, including about 4 miles of the valley. The depth to bed rock is 15

to 60 or more feet. The values were carried in 18 inches to over 7 feet of gravel, with a width varying from 45 to 250 feet. The coarsest nugget was valued at $190. The average values were probably 5 to 10 cents to the pan, but were occasionally much higher. Drifting with steam point was the favorite method of mining in 1904.

Conditions are practically the same on Pedro, Cleary, and Fairbanks creeks, and they all carry about the same amount of water, which in dry seasons will probably be short of the demand. All are dependent on the lower valleys of the larger streams for lumber.

The quantity of gold in the gravels, and their extent, seem sufficient to give the camp a permanence like that of the other placer camps in the Yukon-Tanana country. The depth of the deposits has rendered the work of development a slow one. The claims require capital for their development, and the method used most extensively is steam drifting with points. The expense of working the ground consumes probably from one-third to one-half of the output, and the total production from the close of navigation in 1903 to the end of July, in 1904, was probably not less than $350,000.

No large quartz veins were observed, and the conditions are apparently unfavorable for quartz mining. The origin of the placer gold is probably to be found in the small quartz stringers which occur generally in the schists.

BONNERVILLE DISTRICT.

The large influx of prospectors to Fairbanks led to an examination of the adjacent regions and resulted in the finding of gold along the base of the Alaskan Range 50 miles south of Fairbanks. So far as known the commercial possibilities of this new field have not yet been demonstrated, though a number of miners appear to be satisfied at the outlook. This area south of the Tanana was formed into a new district under the name of "Bonnerville."

The Alaskan Mountains which bound the Tanana on the south are known to be in part made of metamorphic rocks which are quite likely to be mineralized. The range falls off rather abruptly to the Tanana Valley floor, and its northern front is partly buried under a mantle of stratified gravel deposits. These beds were observed by the writer along the Cantwell River Valley, where they are several hundred feet thick, and are probably auriferous. The writer's investigations did not establish the presence of workable placers, but an abundance of fine colors of gold was found in the beds of streams which dissect the gravel deposits. A natural inference is that the heavy gravel beds themselves are auriferous, though opportunity was lacking to make any tests.

These heavy bench gravels lie in such a position that, should they prove to carry values, they could be hydraulicked to advantage. Moreover, their location along the flank of the mountains gives opportunities for bringing water to them under any head desired. If gold has, therefore, been found in this district in commercial quantities, the conditions for exploration seem more favorable than in most of the Yukon camps. It should be borne in mind, however, that the district lies 50 or more miles from water transportation.

BIRCH CREEK DISTRICT.

In the Birch Creek district developments have been relatively slow since the first discovery of gold in 1894, and especially so since the attention of the mining men in the region has been focused on the new Fairbanks placers. Work was carried on in 1904 on a number of creeks, and the production probably equaled that of the previous year, being between $150,000 and $175,000. An attempt to install a small hydraulic plant on Mastodon Creek was unsuccessful because the plant was washed by the floods attending the heavy rains. The steam shovel installed on Mammoth Creek in 1903 was not operated, but this enterprise was only delayed and not abandoned.

In the late summer a discovery of placer gold was reported to have been made near the mouth of what was named Golden Creek. This stream enters Beaver Creek from the west, near the edge of the Yukon Flats. As the main stream is navigable for small steamers to the junction with the Golden, the locality is easily accessible. About 200 men reached the locality before the winter set in, but no extensive prospecting was done. Good authorities state that the surface gravels yield half a cent to the pan. From another source it was learned that a 25-cent nugget had been found. No attempt was made last season to excavate to bed rock, which is probably very deep. Winter digging now going on will doubtless show whether this locality carries any workable placers.

FORTYMILE AND EAGLE REGION.

The Fortymile region continues its record of being essentially a district of small operators, and its production varies little from year to year. Some abortive attempts to establish large mining plants have rather discouraged capitalists from entering this field, which would seem, however, to promise large returns to properly managed enterprises.

At the present time the most important gold-producing area in the vicinity of Eagle is on American Creek and its tributary, Discovery Fork. A hydraulic plant was installed on American Creek in 1903. A flume which had a length of 7,200 feet and a capacity of 1,200 inches brought water under a head of 150 feet. Two hydraulic elevators were to be used, but the water supply was found insufficient for the demands of the plant, and in 1904 modifications of the method were being tried to make a more effective use of the available waters.

Several creeks below Eagle which enter the Yukon from the west have been small producers for a number of years. Among these, Woodchopper and Fourth of July creeks gave employment to a score of miners. Worthy of note is the finding of rich placers in the upper basin of Washington Creek late last summer. One $168 nugget was found in these placers.

Two outfits were working in 1903 on Discovery Fork of Fortymile River, and in 1904 excellent results were being secured here by the use of an automatic dump gate.

Prospecting was active and during the winter of 1903–4 holes had been sunk on an island in Yukon River opposite the town of Eagle. Favorable prospects were reported, but as water had been struck below the frozen ground the work had been discontinued.

The placers of Wade Creek, Walker Fork, and Chicken Creek were said to have yielded well, and Chicken Creek alone is said to have produced $100,000. No work was being done at the "kink" on the North Fork, where a large enterprise had been entered upon.

According to current reports a plan has been formulated to work the placers of the entire Chicken Creek basin by hydraulic methods. It is proposed to bring water by a ditch from the upper part of Mosquito Fork, and it is claimed that thus 200 feet of head can be secured. If this plan is successful it will undoubtedly be followed by others of similar character.

Gold Run, a tributary of Slate Creek about 4 miles long, located in the Fortymile basin about 75 miles southwest from Eagle, was the scene of some activity. The bed rock is schist; the depth of the gravels is about 12 feet. Open cuts are used, and the dump gate is the favorite method of ground sluicing the gravel. Some of the ground is reported to average $30 to the box length. Although no large values have been found, the discovery is of importance in showing the presence of gold in the remote central portion of the Yukon-Tanana country.

KOYUKUK DISTRICT.

The Koyukuk district, though within the Yukon basin, is isolated from the other camps. Its difficulty of access has made it possible up to the present time to mine only the richest placers, but the distribution and occurrence of these indicate that this field will continue to be a gold producer for some time to come. With freight at $90 a ton, not including a sled haulage of 100 miles or more, and wages consequently at $8 or $10 a day, it is manifestly impossible to undertake any extensive operations.

Reports have been received of the discovery during the last season of workable placers on Wiseman Creek, an eastern tributary to the Middle Fork of the Koyukuk. Here 20 men are said to have made good wages. Rich placers are reported to have been found on John River, nearly 100 miles to the west, as well as on Wild Creek, in between. These facts indicate a wide distribution of the placer gold in the Koyukuk district, for the alluvial deposits have been found scattered over an area 50 by 100 miles in dimensions. The last season was less favorable for operations than the previous one and the out-

put was probably much less than in 1903, though exact figures are not available. This, however, led to greater prospecting activity and to the consequent discoveries above mentioned.

COOK INLET REGION.

In the Cook Inlet region placer mining during the past year was practically confined to a few creeks tributary to Turnagain Arm. The Alaska Central Railway, under construction from Resurrection Bay, will be of material benefit to this region. Mr. Moffit describes the region in some detail. Attention will here be directed only to the fact that practically all the mining is now done by means of hydraulic plants. He reports that 7 hydraulic plants were in operation last season.

COPPER RIVER BASIN.

Less definite information is available regarding the Copper River camps, as these have not been recently visited by any of the members of the Geological Survey. It appears, however, that the Chistochina district is holding its own as a producer, and that prospecting with a small production, looking toward important developments, has continued in the Nizina district. All of the Copper River camps are retarded in development by the high transportation charges. It is reported that the cost of carrying supplies to Chistochina is 30 cents a pound in winter and $1 in summer. A tramway, reported to be under construction over the pass by which the trail leads from Valdez to Copper Center, will probably materially reduce this cost, but until rail or wagon roads are constructed the miner in this region, as in other parts of Alaska, can only exploit the very richest placers.

On Slate Creek, in the Chistochina basin, a hydraulic plant has been installed and successfully operated. This is supplied by water through a ditch 2 miles in length. Most of the other operations of this district appear to be confined to "shoveling in" methods, with some ground sluicing.

SOUTHEASTERN ALASKA.

An account of the placer mining in southeastern Alaska will be found on pages 51 and 88 of this bulletin. It appears that alluvial mining during the last year was confined to Porcupine Creek, where no important developments were made in 1904, and to Gold Creek, at Juneau. The Last Chance Company, of Juneau, has constructed a large flume to carry the water of Gold Creek around the basin and has also enlarged its drainage tunnel.

METHODS AND COSTS OF GRAVEL AND PLACER MINING IN ALASKA.[a]

By Chester Wells Purington.

GENERAL STATEMENT OF ALASKAN CONDITIONS.

Placer mining is that form of mining in which the surficial detritus is washed for gold or other valuable minerals. When water under pressure is employed to break down the gravel, the term *hydraulic mining* is generally employed. There are deposits of detrital material containing gold which lie too deep to be profitably extracted by surface mining, and which must be worked by drifting beneath the overlying barren material. To the operations necessary to extract such auriferous material the term *drift mining* is applied.

As nearly all mining in alluvial deposits comes under the head of gravel mining, that term has been adopted in the main for operations described in the report of which the following chapter is a summary. Occasionally, however, the precious mineral sought lies in a matrix of fine sand, or even entirely in the crevices of the bed rock on which the alluvial deposit rests. Obviously the term gravel mining does not cover the cases in which detrital gold is extracted from such matrices, and the general term placer[b] mining has been, therefore, added in the title of this report for want of a name which shall include all operations considered.[c] When in the subsequent matter

[a] The figures given below are extracted from a forthcoming report on the "Methods and Costs of Gravel and Placer Mining in Alaska" (Bulletin No. 263). The data furnish as close approximations as the nature of the work permits. The cost of all supplies, rates of transportation, cost of labor, and description of water, timber, and fuel resources in all important parts of the Territory, as well as full descriptions of all the methods of mining employed, will be given in the final report.

[b] *Placer*, according to a Spanish definition, is a place near the bank of a river where gold dust is found.

Lindley on Mines, sec. 419, makes the following comments:

"Dr. R. W. Raymond (Glossary of Mining and Metallurgical Terms, Trans. A. I. M. E., vol. ix, p. 164) defines the word placer as a deposit of valuable mineral found in particles in *alluvium* or diluvium, or beds of streams. He adds to the definition the statement that, by the United States Statutes, all deposits not classed as veins or rock in place are considered *placers*. As was said by the Supreme Court of the United States (Reynolds *v.* Iron S. M. Co., 116 U. S., 687–695; 6 Sup. Ct. Rep., 601), in distinguishing the two classes of deposits: 'Placer mines, though said by the statutes to include all other deposits of mineral matter, are those in which this mineral is generally found in the softer materials which cover the earth's surface, and not among the rocks beneath.'" It is evident that the term placer mining as used in the present report covers a much more limited field than would be the case were the term placer used in its broad legal sense.

[c] The term *alluvial mining*, used in Australia, is not generally employed in the United States.

the terms gravel deposit, gravel washing, and gravel mining are employed they must be understood, for the sake of brevity, to include the consideration of all classes of deposits in which gold of detrital origin is found.

The term "*eluvial*" has been applied to placer deposits formed by the rotting of rock in place to greater or less depth.[a] Such deposits do not occur in the portions of Alaska visited, and may be excluded from consideration.

In regard to the valuable contents of the deposits, it should be stated that, in all the cases here considered, gold is the mineral sought. Platinum or any minerals of the platinum group have not been found in paying quantity in any part of Alaska. Alluvial tin has been found and mined in the western portion of the Seward Peninsula. The deposits were not, however, visited by the present expedition.[b]

CLASSIFICATION OF ALLUVIAL GOLD DEPOSITS IN ALASKA.

The alluvial gold deposits of Alaska may be classified as follows:

Classification of alluvial deposits in Alaska.

Creek placers	Placers in, adjacent to, and at the level of small streams.
Hillside placers	Placers on slopes, intermediate between creek and bench claims.
Bench placers	Placers in ancient stream deposits from 50 to 300 feet above present streams.
River-bar placers	Placers on gravel flats in or adjacent to the beds of large streams.
Gravel-plain (tundra) placers.	Placers in the coastal plain of Seward Peninsula.
Sea-beach placers	Placers adjacent to the seashore to which the waves have access.
Lake-bed placers	Placers accumulated in the beds of present or ancient lakes; generally formed by landslides or glacial damming.

[a] Eng. and Min. Jour., vol. 77, May 5, 1904, p. 722.

[b] See the report of A. J. Collier (Bull. U. S. Geol. Survey No. 229, 1904) for an exhaustive account of the York tin deposits.

The methods of working the alluvial gold deposits are shown in the following table:

Methods of working alluvial gold deposits in Alaska.

Class of placers.	Method of working.
Creek placers	Hydraulicking.
	Hydraulicking with hydraulic elevator.
	Dredging.
	Open cutting, separate stripping,[a] and shoveling in.[b]
	Open cutting, separate stripping, and horse scraping.
	Open cutting, separate stripping, and steam scraping.
	Open cutting, separate stripping, wheeling, and cable tram.
	Open cutting, separate stripping, and steam shovel.
	Open cutting, separate stripping, track system, and incline.
	Open cutting, separate stripping, track system, and hydraulic elevator.
	Open cutting, separate stripping, track system, and derricking.
	Open cutting, separate stripping, skidding, and derricking.
	Shaft, drifting, and timbering.
	Shaft, thawing, and drifting.
Hillside placers[c]	By the same methods as creek claims.
Bench placers[d]	Hydraulicking.
	Open cutting, separate stripping, and shoveling in.
	Open cutting, separate stripping, and horse scraping.
	Shaft or adit, drifting, and timbering.
	Shaft or adit, thawing, drifting, little timbering.
River-bar placers[e]	Hydraulicking with hydraulic elevator.
	Dredging.
	Open cutting, steam shovel.

[a] Charged to independent account. The stripping generally consists of frozen "muck," a mixture of silt and ice, which is ground-sluiced off.

[b] Covers shoveling into boxes and ground sluice, and rocker work.

[c] Detritus varying from 3 to 60 feet in thickness.

[d] Detritus varying from 5 to 150 feet in thickness; in parts of the Seward Peninsula to 230 feet.

[e] Detritus from 3 to 60 feet in thickness.

Methods of working alluvial gold deposits in Alaska—Continued.

Class of placers.	Method of working.
Gravel-plain (tundra) placers.[a]	Hydraulicking with hydraulic elevating. Open cutting, separate stripping, and shoveling in. Shaft, thawing, and drifting.
Sea-beach placers[b]	Digging shallow pits and shoveling in.[c] Dredging. Special devices.
Lake-bed placers	Hydraulicking.

[a] Detritus from 15 to 150 feet in thickness.
[b] Detritus from 1 to 6 feet in thickness.
[c] The greater part of the gold from the beach sands has been obtained by rockers.

The above classes are based on operations actually seen during the season of 1904. Suggestions concerning the application of other methods to certain forms of deposits are given in the body of the main report.

In the districts visited the deposits under exploitation as above classified were as follows:

Classes of deposits worked in districts visited.

Province.	District.	Class of placer worked.
South Coast	Juneau	Creek and lake-bed placers.
Interior	Atlin	Creek and bench placers.
	Klondike	Creek, hillside, and bench placers.
	Eagle	Creek and bench placers.
	Birch Creek	Creek, hillside, and river-bar placers.
	Fairbanks	Creek placers.
Seward Peninsula	Nome	Creek, hillside, and bench, gravel-plain and sea-beach placers.
	Council	Creek, hillside, and river-bar placers.
	Solomon	Creek and river-bar placers.

In the districts not visited the classes of deposits are as follows:

Classes of deposits worked in districts not visited.

Province.	District.	Class of placer worked.
South Coast	Porcupine	Creek and bench placers.
	Nizina	Do.
	Chisna	Creek placers.
	Sunrise	Do.
Interior	Fortymile	Creek and bench placers.
	Rampart	Do.
Seward Peninsula	Topkok (Nome dist.)	Creek, gravel-plain, and sea-beach placers.
	Port Clarence	Creek and bench placers.
	Fairhaven	Do.
	Kougarok	Do.

MINING METHODS AND CONDITIONS.

The mining of placer gold in Alaska is carried on for the most part during June, July, August, and September. The gold-bearing gravel mined during the remainder of the year by winter drifting does not exceed 15 per cent of the total annual amount extracted. The gold can not be washed from this gravel until the cessation of winter conditions liberates the water in spring for sluicing purposes. The sluicing of the "winter dumps" takes place during the latter part of May.

Many of the methods of mining have been developed within the last ten years to suit the unusual conditions existing in the northern gold fields. Gravel miners from other parts of the world found that in Alaska much of their previous experience proved of no special benefit. On the other hand, men without previous experience in mining, but possessing ingenuity, have occasionally adopted devices which have proved efficient and adequate to meet the northern conditions. Methods which had been condemned or tried with ill success in other countries have given good results in Alaska, while the attempts to apply hydraulic or mechanical methods of established reputation elsewhere have frequently resulted in ignominious failure.

Mining operations have been made difficult by the short available season, the lack of grade to the streams, poor water supply, poverty of timber resources, high cost of labor and transportation, concentration of gold on and in the bed rock and comparatively great thickness of barren overburden, the frozen, or worse still, half-frozen condition of the gravel, lack of wagon roads, and inadequate mining and police

regulations. In spite of these obstacles the wide and fairly uniform distribution of alluvial gold over large areas of Alaska hitherto unexploited, the uniformly healthful and even enjoyable climate of the country, and the proximity of the phenomenally rich gold fields of the British Yukon territory, offer a certain justification for the present energetic prospecting and mining for gold over so extensive an area.

The main impressions derived from an inspection of the placer gold fields of the north are as follows: (1) Operations requiring the installation of expensive plants are frequently undertaken before adequate sampling of the ground has been done; (2) the methods of mining and conveying the auriferous material, while often leaving much to be desired from the standpoint of economy, are, in the main, developing along favorable lines; (3) the gold-washing and gold-saving appliances in use are, in numerous cases, inexcusably crude and inefficient.

The winning of gold from alluvial material is a business difficult both to learn and to conduct successfully. The careful miner, like the careful manufacturer, will give as much attention to one part of his business as to another, irrespective of the scale on which it is conducted. The extensive but not remarkably rich gold-bearing area of Alaska offers a field for men who propose to conduct their operations with energy, intelligence, and economy. To others it can afford only ultimate poverty and despair.

The South Coast province is characterized by heavy grades, abundant water supply, and good timber. Gold-bearing gravels are, however, distributed in small quantity and, however good the conditions for the installation of hydraulic plants, the province remains an unimportant producer of alluvial gold.

The Interior province promises to continue for many years a fairly important producer. Geographically considered, the phenomenal Canadian deposits of the Klondike come under this province. No gravels approaching the Klondike deposits in richness have been found on the American side, but a large area yet remains to be prospected.

Owing to the topographic conditions, low grades to creeks, and insufficient water supply at an available elevation, hydraulicking on any but the smallest scale is impossible. Many of the creek deposits are shallow, and, besides the primitive method of shoveling into sluice boxes, so largely in practice, there is a considerable field for the installation of horse-scraping methods and the installation of simple mechanical plants. Solidly frozen creek deposits exceeding 15 feet in depth can be most economically worked by drifting methods, as heretofore. Experience gained in the Klondike has been invaluable to the miners now developing the new Fairbanks field. There is room, however, for considerable improvement and reduction of expense in the methods employed.

The natural conditions prevailing in the Alaska interior gold field

imply great age and erosion subsequent to any deposition beneath sea level. Topographic conditions exercise a remarkable control over the methods which can profitably be employed in gravel mining, and the prospective miner neglects a vital part of his preparation if he does not study the topographic features of a given district in detail before entering upon operations. In California and Australia the geologic and topographic conditions favor the placer miner. In other countries, notably in Siberia, Alaska, and the Yukon territory, they are inimical to his success. In Alaska, as a rule, alluvial gold is almost entirely lacking where timber and water are plenty, grades steep, and the ground unfrozen. Where gold is distributed in paying quantity water supply is inadequate, timber is poor or altogether lacking, and the miner must provide grade for his boxes and dump for his tailings by artificial means and meet the formidable condition of solidly frozen alluvium. Bench deposits, where gravel can be moved on natural grade, occur in both the Fortymile and Rampart districts of interior Alaska, and have been made to produce a small amount of gold by the hydraulic method. Although it is not impossible that extensive and valuable bench deposits may yet be found, no deposit comparing either in extent or in richness with the famous "white channel" of the Klondike has been discovered.

In that portion of the Alaska interior lying between Circle, on the Yukon, and Fairbanks, on the Tanana, the mountains rise to heights of from 1,500 to 2,000 feet above the level of the streams, have rounded tops, and slope to the intervening valleys at angles which do not exceed 20 degrees, and often are not greater than 10 degrees. The streams and valleys are on a gently descending plain, the grade of which does not exceed 3 per cent, except in the upper one-half mile, and frequently is not over 1 per cent. The mountains are referred to by the inhabitants as "domes," and the word fairly well describes them. They present what corresponds most nearly to the upper segment of a great ellipsoid except in the cases where the erosion has not been sufficient to accomplish the obliteration of a still more ancient topography. This ancient surface, remnants of which are visible on the tops of the highest mountains, was evidently a base-leveled plain which was approximately 2,500 feet above the present drainage plain. Although the base-leveling is apparent to the eye it is not evidenced by the presence of rounded gravel on its surface. The lack of gravel is accounted for by the fact that the second denudation has progressed for a great period, and the comparatively small amount or vertical section of gravel which existed subsequent to the elevation has been worn away.

In the Klondike recent streams have cut the old Pleistocene channels and have reconcentrated the gold.[a] The gold is about equally

[a] See McConnell, R. G., Preliminary report on the Klondike gold fields: Geol. Survey Canada, 1900.

distributed in the old and in the new gravels. From the miner's standpoint, therefore, in the Klonkide region there are two great classes of mining to be considered, namely, creek mining and bench mining. Outside of these two classes there is no mining in the Klondike of productive importance.

In the Birch Creek district, especially on Deadwood Creek, there is a very small amount of gravel in low benches, which may be termed hillside deposits. The bulk of the mining, perhaps 90 per cent of it, is creek mining in its various forms. The terms bench deposit, hillside deposit, and the like are very loosely applied by the miners of the northwest, and the names are given to classes of mining to which they do not in any sense apply. This looseness of nomenclature is apparent in the Fairbanks district, where the term bench mining is applied on Cleary Creek to the operations which are in progress at the left bank of the stream one-fourth mile above the junction of Cleary and Chatham creeks. But whereas the depth to bed rock in the main creek at this point is 18 feet, the depth on the so-called bench, 700 feet to the left, is 53 feet, and the level of the bed rock at which the gravel is found is practically the same. In the one case, namely, in the creek working, the overburden is 6 feet of muck, while in the "bench" to the left the overburden is over 45 feet of muck. The gently sloping side of the valley at this point is unbroken in outline.

Observations along the various producing creeks and from the hilltops have failed to distinguish any traces of bench topography in the Fairbanks district. Such placer mining as is carried on there comes under the head of creek mining. Geological evidence, however, suggests that bench deposits occur in the region lying between the Fairbanks and Rampart districts.

The methods applicable to bench mining at Dawson can not be used in the Fairbanks district, and all thought of applying them must be eliminated. The country being in every sense one of more gentle topography, there is no room for the disposal of tailings from bench operations conducted by hydraulicking.

On Pedro and Twin creeks there are about 2 miles of ground less than 15 feet in depth which can be worked by open cutting, either by shoveling into sluice boxes or by derricking. On a portion of this ground it is possible to handle the water by bed-rock drain. Open-cut mining has also been successful on Chatham Creek near its junction with Cleary. In all other portions of the district, so far as developed, drift mining according to the Klondike system of thawing either with steam or hot-water hydraulicking, hoisting, and conveying by means of the self-dumping bucket on cable tram will probably be found most economical. The writer would suggest the method of underground hot-water hydraulicking to the miners of Cleary Creek, while on Fairbanks Creek steam thawing appears to be advisable. The

efficiency of the hot-water method as used in the Klondike is from 5 to 6 cubic yards per horsepower generated in the boiler, as against 3 cubic yards with steam. The method can, however, be applied only under certain favorable conditions.

In the Seward Peninsula the greater rainfall, larger catchment areas at the heads of the long rivers, and the comparative cheapness with which ditches can be constructed have led to the investment of much capital in long water conduits. For example, a ditch system of 54 miles, built at an expenditure of $300,000 and costing $15,000 annually to maintain, supplies 2,000 miner's inches of water at 360 feet head for four months in the year. Approximately 200 miles of ditches have been built in various parts of the peninsula. Excavations of earthwork for ditch building in the peninsula average $1 per cubic yard.

Hydraulicking without the use of hydraulic lifts is economically impossible, except in extremely rare cases. Bench gravels in the front of Anvil Mountain, facing the sea, can be hydraulicked if water at a sufficient head can be obtained at an expense which is not prohibitive. The remarkable ancient gravel channel which cuts the southern portion of the peninsula from east to west, extending from the Fish River along the Casadepaga and Kuzitrin rivers to Port Clarence, lies at so low a level that the present streams have not cut through it to bed rock. Except where subordinate pay streaks exist in it above the present stream, therefore, the physiographic conditions will forbid its gravels being hydraulicked, while any other form of open cutting is manifestly impossible. It has been little explored, and portions of it may be found rich enough to drift.

Horse scraping, steam or power scraping, derricking, and the application of the mechanical shovel, accompanied in most cases by ground sluicing of the frozen muck, should receive consideration from the creek operators in the Seward Peninsula, where the deposits are less than 15 feet in depth. The low price of winter labor ($2.50 a day and board) should permit of an increasing amount of winter drifting work throughout the peninsula.

It will doubtless eventually be found that the power of water under pressure can be more successfully applied to the working of the average Seward Peninsula placer by generating electric power and applying it to various mechanical devices. While it can not be denied that some of the hydraulic elevator installations are handling the gravel at a profit, the contrivance is a makeshift, and its use forms no part of bona fide hydraulic mining.

MINING COSTS.

The average value of fuels in Alaska as evidenced by present operations is as follows:

Cost of fuels available for use in Alaska.

Bituminous coal, price at Nome	$17 per ton (2,000 pounds)
Crude oil, price at Nome	$3 per barrel
Spruce wood, average price in the interior	$12 per cord

Experience in the Nome district indicates that California crude oil is the most economical fuel available in the southern part of the Seward Peninsula. In the interior of Alaska the price of imported crude oil renders its use prohibitive for mining operations.

The recently exhibited tests of the adaptability and efficiency of gas-producer engines should receive attention from operators who contemplate the installation of mechanical plants in any part of Alaska. There is no question that bituminous coal and lignite can be utilized for gas producers, giving proportionately better results than anthracite. An engineer operating a large pumping plant in the Klondike is of the opinion that even the poor spruce wood available for fuel in interior Alaska can be utilized in the gas-producer engine. The prejudices which exist against the explosion type of engine in the United States are fast disappearing. They have been due to faulty construction of the engines and lack of knowledge of their principle among those who attempt to operate them. The present valid objections to installing gas and gas-producer engines are that these engines are undergoing a process of evolution, and the standard has not been attained. According to Mr. M. R. Campbell, the Government coal-testing plant at St. Louis has demonstrated that a gain of from 30 to 50 per cent of efficiency is attainable in the gas-producing as compared with the steam-producing engine.[a]

The comparatively low cost of California crude oil at Nome renders it a valuable fuel for the mining operations in that vicinity. The satisfactory results from one type of gas engine at St. Louis showed that crude oils of widely varying composition can be used for explosive engines with a higher efficiency than in generating steam.

The purchase of water for hydraulic or sluice purposes is not general in Alaska. In the Seward Peninsula, water under natural head or pumped water is sold to miners to a limited extent. The average price is $1 per miner's inch, twenty-four hours' service, for water under head and 50 cents for sluice water. The inch used corresponds to 1.2 cubic feet per minute. This definition of the miner's inch is not accepted in this report. The miner's inch, according to its best usage, which is followed in this report, corresponds for all practical purposes

[a] See Preliminary report of the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Bull. U. S. Geol. Survey No. 261, 1905.

to a flow of 1.5 cubic feet per minute. It is to be hoped that if the Federal Government ever succeeds in establishing an adequate code of mining law for its possessions a definition of the miner's inch will be included.

The data in the following table have been compiled from statistics collected during an inspection in the summer of 1904 of the placer fields in Alaska, Yukon Territory, and northern British Columbia. Of the statements furnished by operators, only those which are considered reliable have been used. The work attempted had no relation to the sampling or valuing of mining properties, and time did not permit, except in a few cases, the measuring of the ground.

Owing to the varying conditions governing the cost of mining in the north, the Territory has been divided into three provinces. The South Coast province includes the Juneau, Porcupine, and Sunrise districts of Alaska. The Interior province includes the Atlin district of British Columbia, the Klondike district of Yukon Territory, and the Fortymile, Eagle, Birch Creek, Fairbanks, and Rampart districts of Alaska. The Seward Peninsula province includes the Nome, Council, and Solomon districts of Alaska.

The Nizina district of the South Coast province and the Port Clarence, Fairhaven, and Kougarok districts of the Seward Peninsula, none of which were visited, are separately considered.

In preparing the sheet the working costs of 118 different operations were first tabulated with reference to the method employed and to situation. A second table was then prepared, in which the working cost was augmented by an amount per cubic yard based on allowance for depreciation of plant. In general six years was taken as the average life of an individual property, and, except in the case of winter drifting operations, one hundred and twenty days as the working season. It was then assumed that five annual payments are made to a depreciation fund. The fund is equivalent to the cost of plant and maintenance during the life of the property plus six years' simple interest on the investment at 5 per cent. Each annual payment was divided by the season's output in cubic yards, and the amount thus obtained added to the daily working expenses, to get the total output cost per yard, as far as possible. Prices paid for mining property are taken no account of, as they represent an unknown factor.

In cases where expensive plants have been installed the amortization was separately figured for each case.

In cases of shoveling-in and small mechanical plants, the installation and maintenance cost was taken at an average amount for a group of operations in each district. Where the operation implies an additional stripping of overburden, which is always separately charged, the cost was distributed and added to the gravel extraction cost.

From the second table, where the costs were reduced to one figure for each district, a third (the accompanying one) was prepared, giving

as nearly as possible the average cost for each of the seventeen separate methods considered in one or more of the three provinces. Where the operations from which the averages are derived exceed two in number, the fact is so indicated in the table.

The attempt has been made to reject figures which were evidently not representative. The final figure arrived at is not, however, always satisfactory. For example, under No. 5 (the method of working open cut by shoveling into wheelbarrows, wheeling to bucket, hoisting, and conveying to sluice by self-dumping carrier on cable) $2.14 is representative for the Klondike, where seepage water is generally pumped from the pit, and many operators pump the water for sluicing. On the other hand, at a plant in the Birch Creek district of Alaska, mining only 22 cubic yards per day and handling the water by a drain, the cost of operation was $1.50 per cubic yard. In No. 13 (drifting solidly frozen ground, steam or hot-water thawing, hoisting and conveying with the use of the self-dumping bucket) the cost in the Klondike is $1.95, while the higher figure given is arrived at by combining the expensive American camps of Fortymile and Fairbanks, where the cost is $4.63 and $3.56, respectively.

The high cost of hydraulicking with use of hydraulic lift in the Seward Peninsula is caused by the difficulty of moving the gravel to the bed-rock sluice[a] and the expense of the ditches and installations. Hydraulicking by means of water under natural head without the use of the hydraulic lift, or some other means of elevating the material, was not seen by the writer in the Seward Peninsula. It is understood that an hydraulic plant is in successful operation at Bluff, 50 miles to the east of Nome, but there are no data at hand concerning it.

In the interior only bench gravels are hydraulicked. Steeper grades for sluices can be obtained, and the gravel is more easily moved. The high duty of the miner's inch in the Klondike is a large factor in bringing down the cost of No. 1 and No. 16.

It should be distinctly understood, if hydraulicking costs in the interior appear attractively low, that the water supply is exceedingly variable, and that no reliable estimate can be made beforehand of the output of a given season's operations. Furthermore, while much of the bench gravel was originally rich, the pay streaks have been largely drifted out, and the gold is not disseminated through the upper portion of the gravel to the extent that it is in the California gravel banks. With regard to the pumping of water for hydraulicking purposes, the practice can not be too strongly condemned. He is a bold man who attempts it, and a singularly fortunate one who makes a financial success of it.

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[a] This is caused not only by the exceedingly gentle grades of the streams, but also by the shingly character of the material handled.

Mr. Stephen Birch, operating in the Nizina district of Alaska, has courteously furnished for this report a summary of the costs of working placer ground on Dan Creek. These figures are given separately (p. 46) following the table, as they imply a total charge of invested capital in addition to working costs against one season's operations. They are worthy the attention of prospective placer miners.

The cost of shoveling into sluice boxes in the remote parts of the Seward Peninsula is at present from $3 to $5 per cubic yard. Some drifting operations have been carried on in the Kougarok and Fairhaven districts, on which figures are not at hand.

Dredging estimates furnished by trustworthy interior operators place the cost at 80 cents where gravel must be thawed by points ahead of the dredge. In the Seward Peninsula it is estimated that if the property is sufficiently large for a ten-year life to be allowed, a dredge can be operated at the cost of 30 cents per cubic yard. The field for dredges in placer mining in Alaska is extremely limited. In the Seward Peninsula it is not impossible that some of the wide, shallow creek deposits will be worked successfully by means of the steam scraper. The cost of an experimental operation on Ophir Creek was reported to be under 20 cents per cubic yard.

The costs of operating by two mechanical systems in the Seward Peninsula (involving the labor of men in shoveling into cars and tramming to the bottom of an incline, or to a bed-rock sluice leading to hydraulic elevator throat) are, unfortunately, not available for publication. The derricking system, No. 7, however, both in the interior and on the Seward Peninsula, appears to be superior in point of cost to either of the above mentioned, for the working of the average Alaska open cuts.

Frozen ground can not be attacked with success by the steam shovel. Even where it digs the gravel successfully, if men follow it to clean bed rock by hand, the cost of operating is sometimes doubled. The steam shovel has, however, a field in northern placer mining.

Regarding mechanical operations in general, the important principle should be emphasized that the main expense is getting the material into the receptacle which conveys it to the sluice or washing plant. Tramming, even for a long distance and to a considerable elevation, adds a very small proportionate amount to the total cost of working. The establishment of a permanent washing plant, economically situated as regards water supply and dump, should be considered by every Alaskan miner who purposes working the shallow creek deposits which characterize that country. The isolation of the washing operations, together with the adoption of the most economical system of tramming possible, will go far toward attaining the ends of adequate grade and room for tailings, which are the sine qua non accompaniments of successful gravel mining.

Average capacity and cost of gold gravel mining operations in northwestern America.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
	Hydraulicking, no pumping of water.	Hydraulicking with use of hydraulic elevator.	Open cut; shoveling into sluice boxes, including stripping top dirt; no pumping.	Open cut; horse scraping.	Open cut; shoveling; wheeling to bucket; cable tram to sluice.	Open cut; shoveling into cars; track and incline to sluice.	Open cut; shoveling into buckets or skips; skidding or tramming, and derricking to sluice.	Open cut; shoveling into sluice; tailings by hydraulic lift.	Open cut; steam-shovel excavating; track and incline to sluice.	Open cut; steam scraping; generally on stripping work or tailings.	Dredging.	Drifting partly frozen or thawed ground requiring timbering.	Drifting and thawing solidly frozen ground; little or no timbering.	Winter drifting and spring sluicing of dumps.	Mining or stripping overburden by ground sluicing.	Hydraulicking by means of pumped water.	Booming with self-dumping water gate.
SOUTH COAST PROVINCE.																	
Number of operations considered.	6	6	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Capacity, cubic yards, in 24 hours.	833	350	54	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Thickness of deposit, feet	30.3	25	5.6	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Thickness of gravel worked, feet.	30.3	25	3.7	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Cost, per cubic yard [a]	$0.20	$0.31	$2.01	....	....	....	....	....	....	....	....	....	....	....	....	....	....
INTERIOR PROVINCE.																	
Number of operations considered.	13	....	20	....	8	....	....	....	....	6	....	....	7	....	....	4	....
Capacity, cubic yards, in 24 hours.	1,049	....	63	105	162	450	233	184	800	92	1,062	50	75	50	150	830	250
Thickness of deposit, feet	37.4	....	8.6	20	17.5	14	15	8	22	15	35	60	26.4	26.4	9	33	7.5
Thickness of gravel worked, feet.	37.4	....	3.5	[b] 10	4.5	5	9	6	22	8.7	35	4	4.36	4.36	[c] 9	33	[b] 6
Cost, per cubic yard [a]	$0.238	....	$2.39	$0.60	$2.14	$2.43	$1.75	$1.25	$1.46	$0.49	$0.49	$4.25	$3.38	$5.14	$0.17	$0.65	$0.07
SEWARD PENINSULA PROVINCE.																	
Number of operations considered.	....	4	10	5	....	....	....	....	....	....	....	....	....	....	....	3	....
Capacity, cubic yards, in 24 hours.	....	658	145	200	....	....	550	....	1,000	....	700	80	20	83	173	250	....
Thickness of deposit, feet	....	12	6.6	5	....	....	15	....	30	....	8	20	35	85	4	23	....
Thickness of gravel worked, feet.	....	12	3.3	5	....	....	11	....	27	....	8	7	4	4.3	[c] 4	23	....
Cost, per cubic yard [a]	....	$0.89	$1.87	$0.46	....	....	$0.91	....	$0.52	....	$0.43	$4.49	$3.66	$4.61	$0.10	$0.93	....

[a] Lost time, the prices paid for mining property, and the cost of equipment other than that relating to actual mining (e. g., railways, wagon roads, etc.) are not taken into account, and any estimates based on these figures must make due allowance for these expenses; otherwise the costs here given will be found too low.

[b] "Muck" and top gravel.

[c] "Muck" or fine silt and ice; from 50 to 75 per cent ice.

Mr. Stephen Birch, in a letter, gives the cost of placer work on Dan Creek, Nizina district, Alaska, as follows:

By ground sluicing through 20-inch flume: 6,803 cubic yards, $8,781.44, or $1.143 per cubic yard.

By use of 8-inch cotton pressure-hose and nozzle through 20-inch flume: 1,600 cubic yards, $1,457, or $0.91 per cubic yard.

By use of pick and shovel only, through 10-inch sluice box: 2,320 cubic yards, $5,100, or $1.875 per cubic yard.

A 273-foot tunnel, 6 feet by 6 feet, timbered: $1,017, or $3.725 per running foot, or 407 cubic yards of gravel removed, which costs $2.50 per cubic yard.

While the cost given above may seem high, it is because of the fact that it includes the cost of the tools and material now on hand, which were necessary to remove this gravel. Now, if this work is continued for a number of years, the depreciation of the tools, etc., could be charged proportionately. These prices may not be a criterion for future operations in that country, but were our first cost of operation, and any strangers going into that section of country would be apt to run up their costs to these figures.

ECONOMIC DEVELOPMENTS IN SOUTHEASTERN ALASKA.

By F. E. and C. W. Wright.

INTRODUCTION.

The portion of southeastern Alaska which has been called into prominence of late by the international boundary decisions is a narrow strip of coast land extending northwestward from Dixon Entrance and Portland Canal to Mount St. Elias, the highest of a chain of peaks marking the boundary between Alaska and the Yukon district of Canada. From Dixon Entrance to the head of Lynn Canal this coastal area may be described as a partially submerged mountain range, forming in the Pacific Ocean an archipelago of precipitous islands. These rise abruptly from salt water and are separated from each other by deep, narrow fiords and channels, or "canals," the whole forming a remarkable inland passage, which, for scenic effects, is unrivaled by any district in America.

To this field the writers were assigned, with instructions to examine the mining districts and to collect information on the economic conditions at present prevailing. The season's work in this area for 1904 was begun in the latter part of May and completed about the first of October. During June the geologic cross section from the head of Taku Inlet to Sitka by way of Peril Straits was studied, and the mining camps at Funter Bay, Freshwater Bay, and Rodman Bay were visited. In July the senior author made an investigation of the mines and prospects of the Sitka region, while the junior author examined the coal and metalliferous deposits of Admiralty Island. August was spent in mapping the geology along the coast from Sitka to Wrangell, and in making a reconnaissance of the Wrangell mining district. The latter part of the month and the first ten days of September were occupied by the senior author in studying the formations exposed for 180 miles up the Stikine River, which intersects the Coast Range. The junior author, during this time, completed the geologic reconnaissance of the mainland from Windham Bay to Cleveland Peninsula. The remaining weeks in September were devoted to collecting data on the recent mine improvements and the character of the ore deposits in the Ketchikan district.

Because of the illness of the senior author the preparation of this paper has fallen chiefly to the junior author, who has abstracted the notes of the former and presents the following conclusions.

The purpose of this paper is to give a brief summary of the economic developments which have been made during the past few years in southeastern Alaska. A more complete discussion of investigations, accompanied by maps of the region, is in preparation and will be published later.

The total gold production from southeastern Alaska for 1904, excluding that of the Treadwell group of mines, is estimated to aggregate \$275,000. The yield of the Treadwell mines will be approximately \$3,000,000. The production of silver will not be greater than \$30,000, and, excepting small shipments for smelter tests, that of copper has been nil.

GEOLOGY.

To make clear the descriptions of the ore deposits, the general geologic character of the Alexander Archipelago will be briefly described, after which the several mining districts will be treated in turn.

STRUCTURE.

The distribution of the coast formations in wide, extensive belts, all striking in a general northwest-southeast direction with relatively steep dips, facilitates the geologic mapping to a great degree. The arrangement of the sedimentary rocks points to simple structure, and though folds a thousand feet or more in width are prominent among the islands, a duplication of the beds on a large scale has not been observed. Numerous intrusions of igneous rocks, essentially of granite, diorite, and gabbro, have caused a displacement and metamorphism of the sedimentary beds, rendering difficult a grouping into continuous series. The lack of fossils in many of the strata likewise prevents at the present time a definite correlation of the formations.

DISTRIBUTION OF ROCKS.

The main mountain mass between the international boundary and tide water is composed of a light-gray eruptive rock. This rock in general resembles a granite and is usually so named, but microscopic examination proves it to be a granodiorite or a quartz-diorite of coarse crystalline texture. Southwest of this Coast Range invasion are gneissoid rocks and highly metamorphic schists, interstratified with narrow belts of marble. Adjacent to these and bordering the coast of the mainland are argillaceous slates, more or less carbonaceous, including limestones, and these again are followed by extensive belts of more or less schistose greenstone.

Among the islands of the archipelago a particular formation is not continuous along a definite line, and cross sections vary in different latitudes. These islands are composed in the main of wide, intrusive, granitic belts, often forming the core of the islands; of Paleozoic limestone beds in places several miles in width, and of wide areas of intrusive greenstones, usually schistose. On some of the islands black slates are prominent, and probably form the bed rock of many of the channels. Where slates occur in the vicinity of an intrusive belt they are invariably altered to mica-schist and hornfels, and similarly many of the limestone beds have been changed to marble. In the vicinity of Sitka and farther southward, along the Pacific coast, extensive though relatively narrow belts of graywacke form the country rock.

A very much younger group of comparatively flat-lying rocks rest upon the upturned and eroded edges of the older sediments. They comprise a series of sandstones and conglomerates interstratified with numerous coal seams containing fossils of Eocene age.[a] These beds appear to have been deposited in relatively low, flat areas, notably on Admiralty and Kuiu islands, subsequent to the upheaval of the mountain ranges, and were not subjected to the dynamic forces which caused the metamorphism and folding of the underlying limestones and associated strata. These Eocene beds show evidence of only gentle folding accompanied by slight faulting.

Subsequent to the deposition of the coal beds portions of the two above-mentioned islands were covered by flows of andesitic lava, dikes of which are also found on many of the other islands, cutting the older sediments.

MINERALIZATION.

Lode systems, following definite geologic horizons, have been traced for many miles along the west slope of the Coast Range. These lodes occur within limited zones of mineralization, which follow the trend of the sediments and form irregularly disposed concentrations of mineral, sometimes sufficient to make an ore. Such zones were observed by A. C. Spencer and the writer along the mainland, from Berners Bay to Windham Bay, and are described in a general way in the preliminary report on the Juneau gold belt.[b] What seems to be the southern continuation of these mainland belts traverses the Wrangell and Ketchikan districts. They are presumably represented by the mineral locations in Port Houghton, Thomas Bay, Glacier basin east of Wrangell, Bradfield Canal, and Thorne Arm east of Ketchikan.

The data collected from the mineral outcrops and mines of the many islands of this territory have not been sufficient to define the existence

[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 769-908. Brooks, A. H., The coal resources of Alaska: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 515-571.

[b] Spencer, A. C., The Juneau gold belt, Alaska: Bull. U. S. Geol. Survey No. 225, pp. 28-42.

of extensive lode systems traceable over great distances, and it appears from the evidence already gathered that, beyond the boundaries of the main-lode system, mineralization is widely and irregularly distributed. However, on Admiralty Island a mineralized zone may be traced from Funter Bay through the Mammoth group south of Young Bay and to the Johnson prospect on Seymour Canal, 4 miles north of Windfall Harbor. Another may be said to occur on Baranof Island, beginning at Billy basin east of Sitka, traversing the properties in the vicinity of Silver Bay and striking southeastward through the Lucky Chance property, a distance of 12 miles. This zone may also be represented by mineral outcrops which have been located recently at the head of Red Bluff Bay, an indentation on the east shore of Baranof Island.

Mineral-bearing veins and impregnations of copper and gold ores may follow or recur along certain schistose and sedimentary beds, or near contacts of igneous rocks, for several miles, but no well-defined belts of mineralization have yet been traced on the islands to the south.

ORE DEPOSITS.

The ore deposits themselves vary greatly. Some are strong gold-bearing quartz fissures containing free-milling ore of moderate grade, as at Berners Bay, Sitka, and Snettisham. Some are rich stringer leads, occurring in slates and schists, as at Sheep Creek and Funter Bay. Others follow wide dikes of a mineralized basic rock intersecting the slates, as in the Silver Bow basin. Both slates and dikes are cut by numerous gash veins accompanied by sulphides, which also penetrate the inclosing rock and form wide bodies of low-grade ore. Still others are mineralized belts of slate or schist impregnated with sulphides of iron and intersected by numerous stringers of quartz and calcite and occasional concentrations of massive auriferous sulphide. Deposits of this character occur at the Yakima and Nevada Creek properties on Douglas Island, the Portland group on Endicott Arm, the prospects up Spruce Creek at Windham Bay, and the Rodman Bay mines. However, for the most part these ores are of too low grade for profitable mining.

The ore bodies of the Treadwell group of mines, as shown by Becker[a] and Spencer[b] are brecciated masses of intrusive syenite intersected by a network of quartz and calcite veinlets and impregnated with pyrite, which is found both in the veinlets and the rock itself. These deposits occur in carbonaceous slates, the structure of which they closely follow. Similar ore deposits have not been discovered elsewhere in Alaska.

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[a] Becker, G. F., Reconnaissance of gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3.

[b] Spencer, A. C., The geology of the Treadwell ore deposits, Alaska: Trans. Am. Inst. Min. Eng., vol. 35.

In the Wrangell district, farther south, the principal deposits are on Woewodski Island, where the ore bodies consist of wide ledges filling brecciated fissures in the greenstone and carrying principally gold values intimately associated with the sulphides, so that they are not suited for treatment by amalgamation.

Copper is the predominating metal of the Ketchikan district, and deposits composed essentially of copper and iron sulphides occur in wide belts of greenstone in the form of lenticular masses many feet in width and often several hundred feet in length. Such ore bodies are being developed at Niblack and at Hadley for both copper and gold. Contact copper deposits between granodiorite and limestone and in some instances along the contact of a basic intrusive dike, are well presented in the vicinity of Copper Mountain and at the Green Monster group, on the west side of Prince of Wales Island. At Dolomi, Hollis, and Sealevel the deposits, with slate, limestone, and schist as country rocks, consist of free-milling gold quartz ledges, 1 foot to several feet in width, carrying both high and moderately low values in gold.

PLACER DEPOSITS.

The gold-bearing gravel deposits along the southeast coast of Alaska are of low grade and are being worked as such at several localities, namely: Shuck River at Windham Bay, Gold Creek in the vicinity of Juneau, McGinnis Creek 15 miles north of Juneau, Windfall Creek 30 miles north of Juneau, and in the Porcupine placer district. Of these, only two, Gold and Porcupine creeks, have yielded placer gold in profitable amounts, though at the other localities developments are progressing rapidly, and it is hoped that they will soon arrive at the productive stage.

MINES AND DEVELOPMENTS.

SKAGWAY MINING DISTRICT.

The Skagway mining district includes that portion of the mainland territory west of Lynn Canal to a point just north of Lituya Bay, commonly known as Cape Fairweather, and also the strip of land on the eastern side of Lynn Canal north of a point opposite Sullivan Island. The northern termination follows the international boundary between Alaska and British Columbia. The principal mining locality of this section, the Porcupine placer district, was visited and reported upon in 1903.[a] Since that time developments have been continued on Porcupine Creek by the owners of the Discovery and other claims to the mouth of McKinley Creek. The large bed-rock flume, begun last season, has been continued several hundred feet upstream

[a] Wright, C. W., The Porcupine placer district, Alaska: Bull. U. S. Geol. Survey No. 236.

on the Discovery claim, and through it both the creek gravels and the side-bench deposits are being sluiced. The former difficulty in handling large bowlders contained in the gravel wash is to a great degree lessened by the swift current in the bed-rock flume, which transports the greater part to points below the workings. At McKinley Creek operations were not continued the last season, and across the divide on Nugget Creek and on the Salmon River the proposed developments of last year were not accomplished, little work being done.

Glacier Creek, 3 miles west of Porcupine Creek, though idle during the summer, will be opened up this winter during the months of low water. Excepting the annual assessment work and the staking of a few claims, little or nothing has been done farther north, on Bear Creek.

Prospects are reported in the vicinity of Skagway, where there are tunnels and small shafts on many of the deposits. None of these have yet become gold producers and many have been abandoned.

JUNEAU MINING DISTRICT.

The Juneau mining district embodies that portion of the mainland from Cape Fanshaw, in Frederick Sound, to a point opposite Sullivan Island, in Lynn Canal, and includes Admiralty and Douglas islands.

A detailed study of the geology and mines on Douglas Island and on the mainland from Berners Bay to Windham Bay was made in 1903 by Arthur C. Spencer. His report, including topographic and geologic maps of the area, is now in preparation and will soon be available for distribution. In view of the early publication of this report only a brief mention will be made of the late developments on these mainland deposits, while a short description of the coal and metalliferous deposits on Admiralty Island will be added.

TREADWELL GROUP.

During the last year a large 3,500-foot hoist has been installed at the Treadwell mine to replace the small one at the main shaft, which has now reached a depth of nearly 1,200 feet. At this depth the ore body has proved to be of better grade than nearer the surface, and at the 900-foot level the included mass of slate in the central portion of the deposit has disappeared and the deposit has a continuous width of over 300 feet. During the year ending May 31, 1904, the exploration and development work, including drifting, cross cutting, and shaft sinking, amounted to 9,372 feet. The ore milled amounted to 774,595 tons and the ore reserves are estimated at 4,017,289 tons. The value of the ore mined averaged $2.44 per ton, while the total expenses of extraction amounted to only $1.37 per ton.

At the Mexican and Ready-Bullion mines, east of the Treadwell, the developments during 1904 showed but little change in the character of the ore bodies. Statistics on the developments and production

of these mines for the year ending December 31 will not be published in time to include the data in this paper. The mining methods employed have been very clearly described by Mr. R. A. Kinzie,[a] superintendent of the Treadwell mines, and the geology of the ore deposits has been given in much detail by A. C. Spencer,[b] of the U. S. Geological Survey.

Within the Gold Creek drainage area work has been continued, with promising results, at the Ebner, the Humboldt, the Alaska-Juneau, and the Perseverance mines; but, though large-scale operations on these properties have been proposed, no great advancement has been made in this direction.

At Little basin, the Jualpa Mining Company's placer property, within a mile of Juneau, operations have been confined to the installation of a flume sufficient to control the waters of Gold Creek during their highest stages and thus permit hydraulic operations to be carried on with safety. This flume, which follows the south side of the valley slope, is 4,250 feet in length, 20 by 9 feet in cross section, and has a grade of 1.66 per cent. At the head of the basin a dam has been built in bed rock, and gates have been constructed to control the flow of water into the flume or creek bed. A tunnel 2,000 feet long is being extended 400 feet to a point under the basin where it will tap the gravel bed 90 feet below the surface. Early in the spring, when this tunnel is completed, hydraulicking of these auriferous gravels will be commenced.

The Sheep Creek mines, 5 miles east of Juneau, are again being systematically developed and have been good producers in both gold and silver this past year.

MINES SOUTH OF JUNEAU.

The Snettisham mine, approximately 35 miles south of Juneau, has continually produced good ore from its relatively small deposit, and the 20-stamp mill on the property has been in operation during the greater part of the year.

At Sumdum, 50 miles southeast of Juneau, operations have ceased and the mining plant is to be removed, owing to the failure of the quartz ledge in depth, prohibiting profitable extraction. It is doubtful whether mining will ever be resumed at this place.

Still farther south, at Windham Bay, developments have continued on many of the properties, though none of these have as yet proved productive. The mineral belts are low in gold values and though occasional seams with visible gold are found the ores will require very economical methods of extraction to insure profitable mining.

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[a] Kinzie, R. A., The Treadwell group of mines, Alaska: Trans. Am. Inst. Min. Eng., vol. 34, pp. 334–386.

[b] Spencer, A. C., The geology of the Treadwell ore deposits, Alaska: Trans. Am. Inst. Min. Eng., vol. 35.

MINES NORTH OF JUNEAU.

Northward from Juneau along the mainland as far as Berners Bay much attention has been directed to the many prospects, and some promising leads have been discovered. Besides the operations in progress on the placers of McGinnis Creek and Windfall Creek, previously mentioned, investigations have been advanced on the quartz ledges at T Harbor, Eagle River, Yankee Cove, and Berners Bay.

The Peterson group of claims near T Harbor, 20 miles north of Juneau, was bonded and operated the early part of 1904, but, owing to mismanagement, developments were suspended in the fall.

The property of the Eagle River Mining Company, 25 miles north of Juneau and 7 miles from salt water, has been opened by several hundred feet of crosscutting and drifting. The quartz ledge varies from 3 to 6 feet in width and is reported to be of high grade ore. A 20-stamp mill close to the river is in operation and is connected with the mine tunnel, 260 feet above it, by a cable tram. A tramway 3½ miles long has been built from the beach and the remaining 3½ miles is covered by a wagon road. The ore is reported to average $30 per ton.

The Alaska-Washington Gold Mining Company, operating west of Yankee Cove, has completed several hundred feet of tunneling, also a 50-foot shaft, during the year. The ledge is reported to be of high-grade ore and though of no great size is supposed to be of sufficient value to warrant further developments.

At Berners Bay the Kensington mine has been under development during the summer, and a crosscut tunnel 1,800 feet in length has been completed, cutting the ledge 95 feet in width at a depth of 1,400 feet below the surface. The quality of the ore is reported to improve with increasing depth, and the property promises well as a future gold producer. Plans have been made for the erection of a large mining and milling plant, and a town site has been surveyed along the shore below the mine.

At the Jualin and other adjacent mines near Berners Bay, no extensive improvements were accomplished in 1904, and no recent discoveries of much import were made in the vicinity.

MINES ON ADMIRALTY ISLAND.

Funter Bay.—Funter Bay forms a harbor on the east side of Chatham Strait, 10½ miles southward from Point Retreat, the most northern point of Admiralty Island. The rocks exposed along the shores of this bay grade from amphibole to chlorite-schists, and are interstratified in places with beds of marble. There is evidence of much folding throughout this entire series, the anticlines and synclines often being a thousand feet or more in width. The general strike is north-northwest and the prevailing dip southwest. Dikes of a basic character, averaging

several feet in width, crosscut the series in a northeast direction. In this same general course, N. 60° E., are exposures of narrow quartz-filled fissures, a hundred feet or more apart, which form the ore bodies of the principal mines. A second system of quartz veins, considerably larger and striking N. 10° W., is represented at the Portage group of claims, 2 miles from the head of the bay, as well as by the prospects on the southeast side of Funter Mountain. These have not received much development and are reported to be low in gold values.

The Tellurium mine and numerous other claims, 58 in all, comprise the holdings of the Funter Bay Mining Company, established in 1902. Since that time nothing more than the annual assessment work has been accomplished. At the Tellurium mine, close to the water's edge on the south side of the bay, the ore body consists of a quartz ledge several feet in width, that strikes N. 60° E., crosscutting a chlorite-schist country rock. This ledge is opened by two shafts, each 100 feet in depth, and by a tunnel 60 feet in length. The ore—the greater part of which is free-milling—is treated in a 10-stamp mill and is reported to average $8 per ton in gold. The other holdings of this company are located at various elevations on the mountain slope to the south. The ore bodies consist essentially of stringer leads varying from several inches to several feet in width. Assays from many of these small ledges are reported to give high values.

The War Horse mine, 1 mile southeast of the Tellurium, was developed extensively in 1897 by the Keystone Gold Mining Company, and in 1900 it was again operated, but since that time no important improvements have been made. The ledge is very small, averaging 2 feet in width, but is rich in free gold, which occurs finely disseminated throughout the quartz. The developments consist of two shafts 48 and 125 feet deep, besides 320 feet of drifting along the vein. The ore which, after careful hand sorting was shipped direct to the smelter, is said to have had a value of about $100 per ton.

Young Bay.—The continuation of the Funter Bay mineral belt is probably represented by the Mammoth group of mines, situated at 2,600 feet elevation 4 miles south of Young Bay and 12 miles southeast of Funter Bay. The ore deposits here, however, differ from those at Funter Bay in that the country rock—a schist—is heavily mineralized, while the quartz-filled fissures are rare and of very minor importance. Within the three defined mineralized zones are many rich seams carrying galena, sphalerite, and some free gold, and these greatly increase the average values of the ore. These ore belts vary from 25 to 75 feet in width and have been traced several hundred yards along the strike of the inclosing schists. Very high assay values are reported in gold and silver, and small smelter shipments and mill tests have given sufficiently favorable returns to justify the construction of a 1,500-foot crosscut tunnel, which is already 575 feet in length.

This will eventually undercut the ore bodies at a depth of 300 feet. Other developments on this property include several open cuts and small pits, exposing the mineralized rock at various points along the surface.

On the west side of Seymour Canal, 4 miles north of Windfall Harbor, a deposit of copper and iron sulphides is exposed in a quartz-sericite-schist of sedimentary origin. These sulphides have been introduced with stringers of quartz along the strike of the schist and form a mineral zone 20 feet in width. The deposit is located close to the water's edge and has been prospected by a 50-foot shaft and a drift crosscutting the ore body. The low percentage of copper and small gold values in the ore have not encouraged further developments.

At Gambier Bay, south of the entrance to Seymour Canal, chalcopyrite occurs with other sulphides in irregular quartz veins and stringers, which follow the general trend of a calc slate country rock. These deposits are located on the north slope of Cave Mountain at the head of Gambier Bay and on the northeast slope of Mount Gambier. None of the properties have received much attention, most of them even lacking assessment work.

Coal.—The existence of coal beds at Murder Cove, just east of Point Gardner, and in Kootznahoo Inlet north of Killisnoo, has been known for many years, and early, though unsuccessful, attempts were made by the Navy Department to locate workable deposits on this island. Later in the nineties private prospecting was undertaken by many persons, with the idea that the narrow coal seams exposed would become wider in depth or that the small beds indicated more extensive deposits below.

In Kootznahoo Inlet coal is widely distributed in the sandstone conglomerate beds of Eocene age. These beds are but slightly folded and faulted. The coal seams average from a few inches to a few feet in width, and many thousands of dollars have been spent in their development without revealing minable deposits. Most of the properties have been abandoned, and no work was in progress during the last summer.

At Murder Cove only one coal seam has received attention. This is located 2 miles from the head of the cove at an elevation of 500 feet. The inclosing beds are composed of basaltic tuff, breccia, and lava which show much surface decomposition. This occurrence resembles that of the Yukon coal beds.[a] The absence of fossils and the alteration of these beds have been caused in part by the overlying lava flows, which, however, have made the coal much harder and of a better quality. Both the coal beds and rocks in which they occur have been folded sufficiently to render the profitable extraction of the coal a difficult problem. The coal lies in three seams, separated by thin

[a] Collier, A. J., Coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, p. 18.

beds of impure coal and tuff. The average total thickness of coal is about 5 feet. It has been developed by a crosscut tunnel 250 feet in length and a drift of 100 feet along the coal bed. From the drift an incline shaft at an angle of 25° has been sunk to a depth of 180 feet, where the coal bed, found to be displaced, was again discovered after much drifting.

Other coal seams, of no economic importance, however, occur both at Hamilton Bay and at Port Camden in Keku Straits south of Admiralty Island.

The coal in the Alexander Archipelago gives no promise of being in sufficient quantity to make producing mines and thus reduce the cost of fuel. Small amounts, however, may be obtained from some of the coal seams for local use.

SITKA MINING DISTRICT.

The Sitka mining district includes both Baranof and Chichagof islands, the two westernmost islands of the Alexander Archipelago. The rocks strike in a northwest direction, usually have steep dips, and are arranged in wide belts. The eastern coast of Chichagof Island is composed of limestone beds of Carboniferous age, into which have been intruded bands of granodiorite, with their long axis parallel to the cleavage of the sediments. At the south end of the island is a series of chlorite-schists and carbonaceous shales which appear not only to underlie Hooniah Sound, but also to form the country rock in the vicinity of the Rodman Bay mines. Along the narrows of Peril Straits is a wide belt of granodiorite which farther southwest shows such segregation of the basic minerals as to resemble greenstone. Adjacent to this is an assemblage of sedimentary rocks metamorphosed to mica-schists and overlain by slate-graywacke series. In the vicinity of Sitka these strata form the bed rock exposed along the coast and the country rocks of the ore deposits. This slate-graywacke series has been intruded by numerous dikes of varying composition which are associated with or near the mineral deposits.

The ore bodies are irregular, quartz-filled fissures, and are usually parallel to the bedding planes of the slate-graywacke country rock. The ledges vary rapidly in width and are divided into a number of small veins in some places and into a series of small stringers along the bedding planes at others, thus forming a mineral zone composed of stringer leads. The ledges are crosscut by horizontal veins which are apparently unmineralized and of later origin. The values are essentially gold associated with pyrite and pyrrhotite.

Cache mine.—This property, formerly known as the Stewart mine, is located east of and 1¼ miles from the head of Silver Bay at an elevation of 720 feet. It is the only patented claim in this area. The mine is on a quartz ledge which is 4 to 12 feet in width and strikes

N. 70° W., parallel with the slate country rock. It has been opened at several elevations by three tunnels varying from 50 to 150 feet in length, and considerable ore has been stoped out and treated by a 10-stamp mill on the property. The ore is reported to average $7.50 per ton.

Bauer mine.—This mine is 2 miles southeast of Silver Bay and 1 mile south of the Cache mine, at an elevation of 1,700 feet. A crosscut tunnel 900 feet in length reaches the main ledge, which is 16 feet in width at a depth of about 400 feet. It also cuts several smaller quartz veins striking parallel with the formation. The average value of the ledge is said to be $4.50 in gold per ton. Assessment work only has been done on the property this past year.

Lucky Chance mine.—This property is situated in a precipitous mountain range, 2,500 feet above sea level and 4 miles as the crow flies, or 7 by wagon road, from the head of Silver Bay. The quartz ledge has a maximum width of 8 feet where it outcrops; but in the tunnel it is not constant in width and appears to merge into a series of narrow stringers penetrating the mineralized slate hanging wall. The foot wall of graywacke is locally known as diorite, because of its compact, massive structure. A 600-foot tunnel follows the ledge and connects through a raise with a surface pit. The surface improvements comprise a 10-stamp mill, a sawmill, and a water-power plant. High values are reported from parts of this vein, and many specimens of free gold have been obtained.

Billy basin.—The discovery of gold-bearing quartz in this basin, 3 miles east of Sitka, has caused considerable expenditure of money and labor. A good trail was made and a sawmill built, but little was done underground. The extent and value of the ore deposit, therefore, can not be determined, as it has only been opened by two small tunnels, which expose irregular masses of quartz in the slate-graywacke country rock.

Many other prospects, partly developed, notably the Lower Ledge, Bullion, Free Gold, Liberty Lode, Silver Bay group, and the Boston are still held in the above described area, some of which have very favorable surface showings, but lack of capital and inefficient management has caused a suspension of explorations for the past few years.

Rodman Bay.—The mineral deposits 5 miles from the head of Rodman Bay have excited much interest and undergone large developments since their discovery in 1898. The basis of operations at this place is a mineralized belt of much wrinkled slate several hundred feet in width, containing interlaced stringers of quartz and calcite accompanied by sulphides carrying gold. Irregular fissures filled with quartz are also encountered in the tunnel which crosscuts the deposit. The slate country rock has been intruded by dikes of diabase in the

vicinity of the ore body, and a few miles distant by a wide granodiorite belt, both of which have probably been controlling factors in the mineral deposition.

The mine developments include an 800-foot crosscut tunnel, the buildings for a 120-stamp mill, a small power plant, and a narrow-gage railroad 7 miles in length from the mill to the wharf. The ore is reported to be of very low grade, and the work which has been done has not demonstrated the possibility of profitable mining.

Freshwater Bay.—The only mineral locations on Chichagof Island have been made on a gypsum bed outcropping about a mile from the shore of Iyoukeen Inlet, a harbor just north of Freshwater Bay. This deposit is interstratified in a limestone of Carboniferous age, the beds of which have been much folded and sheared. The gypsum is unsuitable for ornamental purposes on account of cleavage and jointing planes, but it is of an excellent quality for the manufacture of plaster of Paris. The stratum has been exposed by an open cut for 50 feet along its strike and for 20 feet in width, and by a shaft for 40 feet in depth, but its full extent has not yet been defined. About 300 tons of the material are in sight. The favorable location of this property and the value of calcined gypsum is sufficient to warrant further development.

WRANGELL MINING DISTRICT.

This mining district extends along the mainland from Cape Fanshaw to Bradfield Canal and includes Kuiu, Kupreanof, Mitkof, Zarembo, Etolin, and Wrangell, and several other smaller islands. Prospecting in this section, has been meager, and at only one locality, the Olympic mine, has there been extensive development and a production of gold.

Duncan Canal.—On the west side of the small island of Woewodski, at the south entrance to Duncan Canal, is the property of the Olympic Mining Company, embracing some 60 claims. Operations have been confined principally to what are known as the "Hattie" Ledge at the lower camp and the "Helen S." at the upper or Smith's camp. The country rock is a greenstone which is probably extrusive and which is more or less schistose. The main cleavage planes strike north-south and dip 70° E. The mineral deposits are quartz ledges from 5 to 15 feet in width, which apparently fill brecciated zones in the greenstones. They strike in a northeast-southwest direction, and are nearly vertical. Large masses of the greenstone are included in these ledges, and the stringers of quartz penetrate the country rock in all directions near the main ledge. Portions of the ledges consist of a network of quartz stringers inclosing the altered greenstone, and sulphides, carrying the gold values, are disseminated in small particles in the quartz as well as in the greenstone. Practically none of the ore is free milling. It concentrates about 18 to 1, which product is said to yield $32 in gold.

The explorations and developments aggregate 1,500 feet of shaft sinking, crosscutting and drifting. On the surface, besides the shaft house, is a well-built 20-stamp mill, a compresser plant run by water-power, and other mine improvements. Work on this property has been suspended since the early part of 1904.

At the head of Duncan Canal are several copper prospects and gold-bearing ledges which are at present receiving considerable attention. Here also the country rock is greenstone-schist which has been intruded by wide dikes of fine-grained diorite.

Near the north end of the east arm, on the west slope of the mountain range, 2 miles from the shore, is the Portage Mountain group of claims. Here four well-defined ledges striking in a northeast direction have been prospected, and it is proposed to drive a crosscut tunnel during the winter of 1904–5 which will undercut the entire system. The ores are in the main chalcopyrite and pyrite, often accompanied by magnetite and pyrrhotite.

On the west side of the east arm is another group of locations on what is supposed to be a continuation of one of the above-mentioned ledges. This property is also to be developed this coming year.

A third prospect is located 2 miles up the creek, entering the north side of the west arm of the canal. At this point the ore body is a mineralized limestone which occurs in the greenstone-schist series, and is in places traversed by seams along which a concentration of the mineral has been effected. The ore is pyrite with some galena, from which favorable assay returns are reported. Explorations on this property have just been started and the extent of the ore body has not been determined.

A somewhat novel feature is the presence of gold-bearing quartz ledges in the intrusive granite belt on Woronkofski Island. These are situated on the north end of the island, on a point called the Elephant's Nose, and have been located as the Exchange Group of claims. The quartz ledges are later than the granite, and in them are many inclusions of granite masses, altered, and more or less impregnated with mineral. Two ledges averaging 12 feet in width have been opened by two tunnels and open cuts, and from these exposures fair gold assays are reported. These properties have remained idle for the last few years.

Glacier basin.—Glacier basin is a glacially eroded depression at an elevation of 2,000 feet on the mainland, 14 miles due east of Wrangell and 8 miles from tide water. The mineral deposits are all found in the schist series adjacent to the Coast Range intrusive belt to the east. Their general trend is northwest and the dip northeast. Narrow granitic belts and porphyritic dikes, probably offshoots from the main belt, intersect this schist series at very oblique angles, and probably have had considerable influence upon the deposition of the ore. In

the vicinity of the porphyry dikes and along their contacts are ledges of massive galena and chalcopyrite, usually parallel with the schistosity of the formation. The principal deposit of Glacier basin is found between two porphyry dikes striking N. 30° W. and dipping northeast at an angle of 45°. Two tunnels 50 feet in length expose the ore body, which is about 20 feet in width. The principal mineral is concentrated along the foot wall. The ore is reported to carry values in silver, lead, and copper.

On the Margery claims, below the basin, the deposits are essentially galena ores, occurring in stringers 1 foot to 5 feet in width, which follow a definite zone parallel with the schist. This vein system has been opened at an elevation of 1,500 feet above sea level by a tunnel 40 feet in length. Farther northeast on the same claim is an open cut exposing a 12-foot ledge which is rich in galena and which has been traced several hundred feet along its strike. Assays from this are reported to be high in silver and gold as well as in lead. The ores are galena, sphalerite, chalcopyrite, native silver, cerrussite, and limonite.

The "Ground Hog" basin claims, 4 miles north of the Margery claim have been developed to some extent during the year and show favorable assay returns. The ledge is over 6 feet in width and not unlike the ledges of Glacier basin.

Bradfield Canal.—On Ham Island, at the north entrance, to Bradfield Canal, is a deposit of a blue, coarsely crystalline marble. This is favorably situated and the marble is of good quality, containing few jointing cracks. The exposure is 50 feet high and 100 feet long. Tests of this rock have been made, and it is reported to be suitable for building as well as ornamental purposes.

KETCHIKAN MINING DISTRICT.

Two weeks were occupied in making a hasty visit to important mining localities of this region, which had been studied in 1901 by Mr. Brooks.[a] This examination was deemed necessary, owing to the change in economic conditions and to the rapid developments in progress at some of the mines.

From the present investigation copper appears to be the most important metal of this district. Gold and silver values are next in consequence, both separately and in connection with the copper ores. Other metals, such as lead, zinc, and nickel, are found, but will be be mined, if at all, only as by-products.

COPPER.

The occurrence of this metal is chiefly confined to Prince of Wales island, which forms the western half of the Ketchikan district. The bed rocks of the island are argillites and white limestones, closely asso-

[a] Brooks, A. H., The Ketchikan mining district, Alaska: Prof. Paper U. S. Geol. Survey No. 1.

ciated with greenstones. As the result of general metamorphism the limestones have been changed to marble, the greenstones to schists, and the argillites to crystalline schists and graphitic shales. Intruding these older strata are masses of quartz-diorite occurring as stocks miles in width, together with dikes and small areas composed of a more basic rock. On the east side of the island from Cholmondeley Sound northward, including Kasaan Peninsula and the west side of Cleveland Peninsula, the Kasaan greenstone forms the country rock. This, as described by Mr. Brooks,[a] is believed to be largely effusive and later than the bed-rock series. It is of economic interest because of its association with the copper ores on Kasaan Peninsula and in the Skowl Arm region.

Niblack Anchorage.—Niblack Harbor forms an indentation in the southeast shore of Prince of Wales Island, and is 36 miles by water from Ketchikan. The mountains rise with steep ascent from the water's edge to peaks 2,000 to 3,000 feet in elevation. Greenstone is the country rock in the vicinity of the mines, but this, in places, has been altered to sericite, chlorite, and amphibole-schists. These original greenstones are intrusive into the older sedimentary rocks, which occur farther north and south but do not outcrop in this harbor. At a distance of 2 miles on the slopes to the north of Niblack Anchorage is an intrusive dioritic stock, a mile or more in width, and of later date than the greenstone. A similar intrusive mass occurs to the south along the north shore of Moria Sound. The relation of the copper deposits to these distant dioritic stocks was not determined, though it is possible that they owe their genesis to the after action of the dioritic invasion.

The ore bodies occur both as small and irregular veins and as mineralized zones. Though the veins are rich in values, they will never be of as great importance as the extensive mineralized zones. Chalcopyrite, with pyrite and pyrrhotite, carrying gold values, are the principal ores.

Developments during the past two years have been confined to ore bodies exposed on the Judge claim, which lies close to tidewater at the head of Niblack Anchorage. On the original locations of the Lookout Group, situated at an elevation of 1,500 feet, on the south slope of Niblack Anchorage, only the annual assessment work is being done. The deposits at the Judge claim are large lenticular masses from 10 to 100 feet in width and 100 to several hundred feet in length and depth. These are separated by unmineralized belts of greenstone-schist. The ore—essentially a massive sulphide of pyrite and chalcopyrite—occurs in a matrix of altered greenstone, and appears to fill sheared zones, as both masses and fragments of the greenstone occur, completely surrounded by the mineral. Small veinlets of sulphide,

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[a] Op. cit., p. 97.

ssociated with quartz, occur in parts of the workings and form what s locally termed a jasper ore.

The developments at Niblack anchorage at the time of the writer's isit consisted of an inclined shaft 180 feet deep and, leading from his at three different levels, 660 feet of drifting and crosscutting.

The ore is said to carry 5 per cent copper and $1.50 to $2 in gold alues. Concentration of this ore would not be practicable owing to s massive state and the high percentage of valueless iron pyrite, hich can not be separated from it except by smelting or some pro-ess of solution and reprecipitation. The mine is most favorably tuated and the ore from the shaft may be transported in cars directly o scows or barges for shipment to the smelters. A water-power at he head of the anchorage is controlled by the company and can be sed to develop enough electric power for mining purposes.

Kasaan Peninsula.—On the northeast side of Kasaan Peninsula is a roup of seven claims, the property of the Brown Alaska Company. his is one of the recent discoveries in the vicinity of Ketchikan and by far the most extensively developed, especially in regard to urface equipment. The country rock near Hadley, as well as of the reater part of the peninsula, is composed of the Kasaan greenstone ith occasional intervening beds of much wrinkled limestone altered o marble. Interstratified in the limestones are beds of magnetite, ften carrying chalcopyrite. Dikes of felsite and more basic rocks re intruded into both the greenstone and sedimentary beds. The eneral trend of the sedimentaries is north-south, and the dip is to the est. The deposits form irregular lenses generally concordant with he dip and strike of the formations, and seven such masses have thus r been discovered, varying from 100 to 150 feet in length and 20 to 0 feet in width. The ore, essentially chalcopyrite, is said to contain 5 to 4.5 per cent copper, with $1 to $2 in gold values. The peculiar ccurrence of these copper deposits and the intimate relation of the trusives and magnetite beds to the ore bodies will be treated in etail in the more extended report.

Considerable underground development of the ore bodies has been ccomplished. Two shafts 40 and 80 feet deep, and three tunnels from 0 to 200 feet in length, with many drift tunnels, expose the deposits various elevations. On the surface a 500-ton smelter has been ected, also a large compressor plant and various other necessities for e economical extraction of ore.

On the southwest side of the peninsula is the Mount Andrew group claims on copper deposits, which have the same manner of occurrence the deposits last described. A tunnel 800 feet in length has been iven, but no work was in progress this season. The value of the e, chiefly chalcopyrite and magnetite, is said to be 4½ per cent in pper and $1 to $3 in gold.

Hetta Inlet.—The Copper Mountain-Sulzer properties are on the south side of Hetta Inlet, a deep indentation in the southwest coast of Prince of Wales Island. The ore occurrences in this area, though rather widely scattered, are all of copper, with a few dollars per ton in gold values, and are remarkably similar in character. The ores are found principally along the contacts of a limestone, with either granite belts or diabase dikes. The original ores are principally chalcopyrite, pyrite, pyrrhotite, and magnetite, with quartz, calcite, garnet, and epidote, as gangue minerals. In many of the deposits surface oxidation has altered the sulphides to a considerable depth and formed carbonate and oxide ores.

Alaska Copper Company.—At the Alaska Copper Company's property, on the south slope of Copper Mountain, development follows a contact of granite with limestone and shows the usual contact phenomena. This ledge, known as the "New York," is located at an elevation of 3,300 feet near the summit of a steep mountain slope, and is exposed by large open cuts and short tunnels. At 2,400 feet elevation a tunnel, already 1,400 feet in length, is being driven to undercut the ledge below the surface workings, and this purpose was almost accomplished at the time the property was visited. A few thousand feet east of the New York ledge is the Oregon ledge, which is over a hundred feet in width, but of lower-grade ore. This has not as yet been developed. The extent and final average value of the ore can not be determined from the present indications. However, the surface showings appear to justify a continuation of the proposed developments. A 250-ton smelter has just been completed, a water-power plant sufficient for all purposes has been built, besides a 5,000-foot-cable tram from the uppermost workings to the smelter.

Alaska Industrial Company.—Two large groups of claims are being developed by the Alaska Industrial Company, namely, the Jumbo group of 29 patented claims, on the north slope of Copper Mountain, and the Green Monster group, 6 miles east of Copper Mountain. On each of the above groups several copper-bearing ledges have been exposed by tunnels and open cuts, and on some there are large surface exposures of rich chalcopyrite ore. On the Jumbo claims diabase and limestone are in most cases the inclosing rock. At the Green Monster group the deposits are more often at or near the granite limestone contact. As yet neither mining nor water-power plants have been built, though these will probably follow when further mine developments bring to view sufficiently large ore deposits to warrant such construction.

GOLD.

Though gold is not extensively mined in the region under discussion it has been sought in many localities. Work beyond the annual assessment requirements has been done only at Dolomi, on the southeast side

of Prince of Wales Island; at Hollis, on the northwest side of Twelve Mile Arm and in the central part of the island; at the Hoadley Brothers' claims, 2 miles north of Ketchikan; at Thorn Arm, on Revillagigedo Island; at Miller's camp, on the east shore of Gravina Island, and on the southeast side of Dall Island. During the past summer operations were in progress on all of the above excepting the Sealevel mine at Thorn Arm, and the proposed future developments will probably cause these properties to rank as good gold producers. Besides the eventual gold production from the quartz ledges considerable copper will also be obtained from the above-described mines.

Dolomi.—In the vicinity of the town of Dolomi, which is on Johnsons Inlet, 36 miles west of Ketchikan, nearly a hundred locations have been made, but investigations have been confined principally to the Valparaiso, the Amazon, and the Golden Fleece claims.

The ore deposit at the Valparaiso consists of a quartz ledge 6 to 8 feet in width, occurring in a crystalline limestone country rock. A concentration of the gold values has taken place along pay streaks on the foot wall of the ledge and from this rich portion considerable ore, averaging $200 to $250 per ton in gold and silver values, has been been recovered. The minerals are principally free gold, tetrahedrite and pyrite, with quartz and calcite as gangue. Three inclined shafts 100, 80, and 35 feet in depth and a few hundred feet of drifting and stoping expose the ledge at different points along its strike. The ore is well adapted for concentration, and when a mill is installed good returns may be anticipated across the entire width of the ledge.

The quartz deposit at the Amazon claim is composed of ore of somewhat lower grade, but the gold values are apparently uniformly distributed. Its width varies from 10 feet at the surface to 1 foot at the bottom of a shaft 123 feet in depth. A calcareous schist, in places brecciated with quartz as the binding material, forms the inclosing rock. Developments on this relatively recent discovery give very encouraging results, and the ore value is reported to vary from $15 to $30 in gold.

The most extensively developed property is the Golden Fleece mine, located on James Lake, 2 miles from tide water, and connected with the wharf by a well-graded tramway. The quartz deposits here also have a dolomitic limestone as country rock, which is cut by many small diabase dikes. A peculiar and advantageous feature of this mine is the occurrence of several limestone caverns which apparently follow the mineral deposits. The quartz bodies are irregular lenses, slightly cutting the bedding planes and varying from a fraction of a foot to 8 feet or more in width. The dip is to the southeast at an angle of about 40°. On the main ledge developments consist of two 200-foot tunnels which connect with many of the above-mentioned

caverns. On another near-by ledge a shaft has been sunk to a depth of 80 feet. The present 5-stamp mill is to be enlarged to a 15-stamp mill during the winter.

Hollis.—The bed rock in this vicinity is composed mainly of crystalline limestones and carbonaceous slates with intercalated sills of greenstone, both massive and in part altered to chlorite or amphibole-schists. Parallel to and slightly cross-cutting the slates are dikes of a bluish-gray porphyritic rock, in or near which the ore deposits occur as true fissure veins.

The properties which have received the most attention are the Puyallup group, 1¼ miles west of the bay, and the Crackerjack mine with its southeastern extension, the Hollis claim, 2 miles west of Hollis.

The first mentioned, the Puyallup claim, consists of a rich quartz-filled fissure, from 4 inches to 2 feet in width, cutting diorite-porphyry country rock. This has been developed by two tunnels, the lower one 1,135 feet long, the upper 220 feet long. At the end of the longer tunnel the vein has been lost and has not as yet been rediscovered. On the property a 5-stamp mill treats the ore, and 85 per cent of the gold is found to be free milling.

The vein which is worked on the Crackerjack claim lies principally along the upper contact of a porphyry dike cutting the schist, though in places it enters the porphyry. The slate is more or less graphitic and finely bedded. It strikes N. 25° W. and dips southwestward at an angle of 35°. The porphyry dike is in the main parallel with the bedding of the formation, and varies from 2 to 20 feet in width. It is said that this ledge, which varies from 1 foot to 5 feet in width, may be traced on the surface for more than 3 miles. The values, chiefly free gold with pyrite, are found in ore shoots parallel to the dip of the ledge. The deposit has been opened by an 800-foot tunnel at an elevation of 800 feet above tide water, and a second tunnel of about one-half that length. An average value of $15 per ton is reported. On the extension claims above this are two tunnels, one 120 feet and another, at an elevation of 1,450 feet, 400 feet in length. In each of these the conditions of occurrence are similar to those above mentioned, and the character of the veins is very uniform.

About 7 miles northwest of Hollis are located the Commander group, Flora Nellie, Dew Drop, Red Jacket, Summit, and Rose claims, which are still in the prospecting stage. The quartz ledges here average from 2 to 4 feet in width, and are quartz-filled fissures following slipping planes in a porphyry dike which in places has been rendered schistose. Ore from the various tunnels, essentially galena, pyrite, and chalcopyrite, is reported to average from $25 to $50 per ton, and with more favorable transportation facilities these properties may make profitable mines.

The Cascade mine is located about 3½ miles west of Hollis. The ledge averages 2 feet in width and occurs as a filling along a slipping plane in an altered basic eruptive rock. The chief development work consists in two tunnels 50 and 240 feet in length. The average value of the ledge has not been determined as yet. Visible gold is not uncommon.

Gravina Island.—Miller's camp, the only prospect on the island which has been developed considerably, lies on the east side of Gravina Island, about 4 miles from Ketchikan. The formation consists largely of schists of various types with a northwesterly strike and a northeasterly dip. Certain bands of the series, 5 to 10 feet in width, are heavily mineralized with sulphides and constitute the ore bodies. Two of these bands have been discovered and prospected by shafts 50 feet deep. The gold value is reported to average $10 to $15 per ton. Surface improvements consist of a 5-stamp mill and mine house. In both shafts a highly altered basic intrusive dike has been found crosscutting the formation obliquely. The present outlook seems to warrant greater developments.

The Hoadley Brothers' claims are located 2 miles north of Ketchikan and one-fourth mile from tidewater. The veins, although narrow, occur usually within a syenite dike, intrusive into the schist country rock. Two different sets of veins can be distinguished, the younger of which is remarkable for its high gold content.

Dall Island.—On the east side of Dall Island, 2 miles from the south end, are the recently located Elk and Virginia groups of claims. These are on four different quartz ledges, which vary from 5 to 30 feet in width and occur in both limestone and slate. The gold values are associated with chalcopyrite and galena and ore assays varying from $10 to $50 are reported. This property has been worked during the past summer and the developments will continue throughout the winter.

The Mount Vista group, in the central part of the east shore of Dall Island, is located on a mineral belt in limestone and consists of numerous stringers and small masses of a tetrahedrite ore carrying high values in gold and silver. This property is being opened by several small tunnels and the ore exposed is said to assay well.

Revillagigedo Island.—The "Sealevel" mine, located at the head of Thorne Arm, was largely worked during 1900 and again in 1902–3, but since the summer of 1903 all operations have ceased. Since Mr. A. H. Brooks's visit to this property in 1901 a 30-stamp mill has been erected and a water-power plant built. Most of the ore between the surface and the lower level has been stoped out and milled, and probably owing to the lack of sufficient ore to supply the 30-stamp mill and the costly method of handling the ore, mining was discontinued. The ore

deposits comprise two quartz-filled fissures which are in part inclosed in a porphyritic dike; but at the north end of the claim these leave the porphyry and enter a greenstone-schist which here forms the country rock. The ledges are about 15 feet apart, average from 2 to 6 feet in width, and have been traced over 2,000 feet along the surface. The ore is reported to carry $6 in gold per ton.

Other prospects.—In the vicinity of Ketchikan and on Gravina Island are many other prospects more or less developed, and some with favorable ore exposures. A discussion of these, however, is not possible in this brief summary.

MARBLE.

During the last few years much attention has been paid to the marble deposits on the Prince of Wales Island. The largest of these is located close to tide water, 3 miles from Shakan on the northwest side of the island. The deposit has been developed by several open cuts, which expose a white, finely crystalline marble. Jointing planes and cracks are reported to occur in this rock which will prevent the mining of large slabs or columns, though its favorable location will probably make the deposit of value for building stones.

At the head of North Arm, west of Dolomi, on the east side of Prince of Wales Island several claims have been located on a marble deposit similar in character to the Shakan deposit. It is exposed for a moderately large width and the marble is reported to be of good quality.

THE TREADWELL ORE DEPOSITS,[a] DOUGLAS ISLAND.

By Arthur C. Spencer.

INTRODUCTION.

Douglas Island, one of the smaller islands of the Alexander Archipelago, is separated from the mainland of southeastern Alaska by a narrow fiord known as Gastineau Channel. The four mines of the Treadwell group are located near its inland shore, and the towns of Douglas and Treadwell owe their 2,000 inhabitants to the mining operations, while Juneau, with somewhat greater population, lies on the adjacent mainland, about 2½ miles northwest of Treadwell. The distance by steamer from Seattle, Wash., to Juneau slightly exceeds 900 miles, while Skagway, the terminus of the Yukon and White Pass Railroad, lies 95 miles to the northwest, and Sitka about the same distance in a southwesterly direction.

The most southeasterly mine, the Ready Bullion, is 3,000 feet from the nearest workings of the Alaska-Mexican mine, and the intervening ground is supposed to be practically barren. The workings of the Mexican mine extend, however, almost to those of the Seven Hundred Foot property, and the latter connect at several levels with the tunnels of the Alaska-Treadwell mine. There is thus an almost continuously developed ore body for a distance of about 3,500 feet. Although the workings have revealed several separate ore bodies, and certain distinctions are made in the character and occurrence of the ores, the mines are all located on the same lead, and the ore material is practically of one nature and of identical origin throughout. As a whole, therefore, the deposits may be conveniently designated by the name of the first discovered and largest mine.

GEOLOGY OF THE REGION.

The geology of the Juneau region and of southeastern Alaska as a whole resembles, in many ways, that of the gold belt of California. The rocks of both regions are in large part of identical character, and some of them correspond in age and in the nature of their metamorphism. There is also a marked similarity in the occurrence of the

[a] This paper, with a more extended account of the geological features of the region, was printed in the Transactions of American Institute of Mining Engineers, Lake Superior Meeting, Oct., 1904.

gold veins and in the general effects of mineralization, and some of the broader facts suggest that the dates of vein and ore deposition also correspond closely, though more extended and further detailed studies must be made before definite proof of this can be obtained.

The formations of the mainland may be thrown into three lithologic groups, which are distributed in parallel zones following the general trend of the coast. Two of these groups, the schists and the slate-greenstone band, are mainly metamorphosed sediments, although the greenstone beds represent ancient volcanic flows of andesite and basalt. The third group is composed of the great complex of intrusive granular rocks, mostly dioritic, which form the mass of the Coast Range. The general structure of the region is monoclinal, strikes being usually northwest and southeast and dips always toward the northeast.

Very general mineralization has taken place since the diorite-intrusions, the age of which has recently been determined as later than early Cretaceous. [a]

THE ORE BODIES.

GENERAL FEATURES.

The ore bodies consist mainly of mineralized albite-diorite occurring in the form of intrusive dikes in black slates, the structure of which they closely follow. These slates are metamorphosed shales in which both original bedding and slaty structure strike northwest and southeast (fig. 1) and dip about 50° on the average toward the northeast. The ore-bearing dikes belong to a series of intrusions which appear interruptedly along the strike for a distance of about 3 miles in a zone approximately 3,000 feet wide. In the greater part of the intruded area exposures are few, and only small dikes outcrop on the side toward the center of the island. On this side the zone seems to be irregularly limited, but next to the shore of Gastineau Channel the border is defined by a heavy bed of greenstone running parallel with the slates and the intrusive dikes and dipping with them toward the adjacent channel. The mineralized dikes that constitute the known minable ore occur just beneath this greenstone, which thus constitutes the hanging wall both of the intrusion zone and of the ore bodies. Many of the dikes of albite-diorite away from the hanging wall have been greatly altered and impregnated with pyrite, but workable ore bodies have not yet been discovered in them.

The strike of the different rocks is regular in the main, and, being slightly oblique to the channel, the outcrops of the ore bodies recede from the shore toward the northwest. The base of the greenstone

[a] During the summer of 1904 Mr. C. W. Wright found Lower Cretaceous strata on Admiralty Island infolded with slates and greenstones belonging to the same belt as those of Douglas Island. The diorites, which invade the slate-greenstone group of rocks, are either younger or of the same date as the folding and are therefore younger than the Lower Cretaceous beds.

hanging wall strikes the shore of the island about 1 mile below the Ready Bullion mine, at first running inland and then back to a point below high water just below where the southernmost body of diorite is exposed in the open pits of the Ready Bullion mine. Reappearing within a few hundred feet, it bends sharply and is next exposed in the southeast pits of the Mexican mine. From this point it is traceable in a nearly straight line through the Seven Hundred Foot and Treadwell workings and for a distance of several miles beyond.

In the vicinity of the mines there are no dikes of diorite on the channel side of the greenstone, but about 1 mile to the northwest two croppings have been noted, and Juneau Island, in Gastineau Channel about 2,000 feet from the foot wall, is composed of similar rock, which is somewhat impregnated with pyrite.

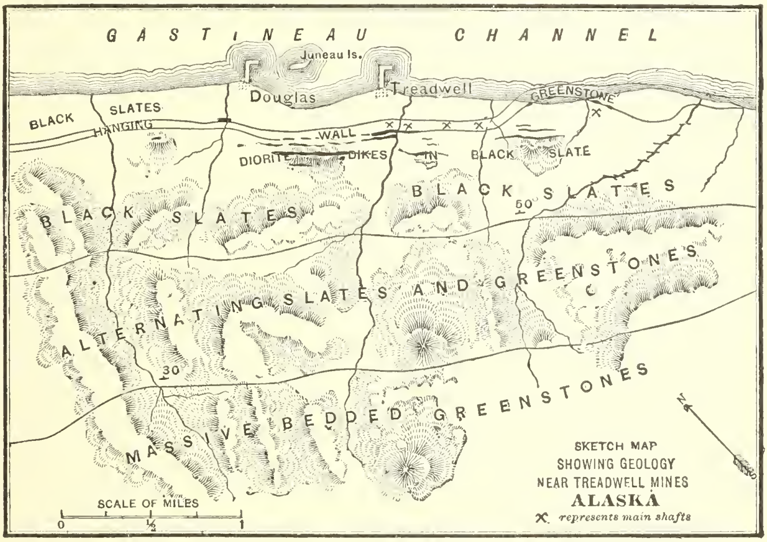

FIG. 1.—Sketch map showing geology near Treadwell mines.

Besides the mineralization of the igneous dikes, the black slates of the same general belt on both sides of the greenstone band contain occasional veins and systems of quartz stringers following the structure. Veining of this sort has been particularly noted along the foot wall of the Treadwell greenstone for a distance of several miles beyond the mines. Assays of about $6 per ton in value have been obtained in some places, but there has been no systematic attempt to develop these stringer leads, and their value is doubtful.

The rocks occurring in and near the mines, which will now be described in greater detail, are the following: The greenstone hanging wall; the slate country rock, inclosing both greenstone and ore bodies; the dikes and lenticular masses of diorite, some of which constitute the ore; and a few small dikes of basalt.

GREENSTONE.

The hanging-wall greenstone forms a prominent bed or stratum about 300 feet in thickness where measured in the mines, but varying somewhat from this figure in different parts of its outcrop. So far as can be determined, it follows the structure of the slates, striking with them from southeast to northwest, and dipping northeast toward the near-by channel, beneath which it has been followed to a depth of about 900 feet in the lowest workings. The outcrop is practically continuous for 4 miles northward from where the greenstone first appears on the shore of Douglas Island. Then the bed thins out and is wanting for a few hundred feet, but it soon reappears and may be followed for an additional 2 miles, until it is lost beneath a heavy covering of vegetation.

As a rule, the rock is greatly altered, and in places it is even schistose or slaty, but portions are sufficiently unchanged to indicate the original composition and structure. In the vicinity of the Ready Bullion mine the rock is granular, consisting mainly of coarsely crystallized hornblende, though it contains a great deal of magnetite and some pyrite. A specimen from the Mexican workings, which might be called andesite, contains porphyritic crystals of plagioclase and augite in a decomposed groundmass, which seems to have consisted largely of small prismatic feldspar crystals. The secondary minerals are chlorite, epidote, serpentine, and calcite. Beyond the workings toward the northwest the greenstone is a fine-grained diabase.

The greenstone was called gabbro by Becker, who regarded it as later than the rock of the ore bodies, but there is now sufficient evidence to establish the opposite age relation, and reasons exist for doubting its intrusive nature. The inclusions of light-colored rock fragments in the greenstone, which form the basis of Becker's conclusions, are represented in his collection by a specimen and a thin section, showing a distinctly outlined fragment of grayish granitoid rock inclosed in greenstone; but the diagnostic value of this occurrence is open to doubt, since at several points in the region pebbles and fragments of similar material occur in the volcanic greenstone breccias at different horizons in the series of interbedded slates and greenstones, showing the existence of an available source of granitoid material prior to the deposition of the slates and the outpouring of the contemporaneous lavas.

In the open pits of the Seven-Hundred Foot and Mexican mines the exposed lower part of the greenstone bed is very schistose, and this slaty rock forms both walls of the ore body. Between the ore and the black slate usually forming the foot wall there is a plate or layer of chloritic schist of somewhat variable thickness, evidently identical with the schistose or slaty greenstone of the immediate hang-

ing wall, and the latter grades off into the massive rock. This relation suggests that the locally developed schistosity of the greenstone existed before the intrusion of the diorite dikes or was produced at the time of their invasion, and in either case the greenstone must be the older rock. More definite evidence in the same direction was noted in an old stope above the 220-foot level in the Treadwell mine. Here the main mass of diorite lies below all of the greenstone, but the latter is somewhat schistose, and a narrow offshoot from the diorite cuts across this secondary structure for a distance of about 3 feet, and then follows the schistosity parallel with the wall of the large ore body.

Without the above proof that the diorite is intrusive in the greenstone, several general considerations would lead to the probability of this relation. In the region at large the dioritic rocks invariably cut the bedded greenstones, and in Sheep Creek they are even later than the gabbro dikes which follow the structure of the inclosing rocks approximately. None of the basic intrusives which are evidently later than the Coast Range diorites show any tendency to follow the structural trend of the region, but, like the small basalt dikes in the Treadwell mine, they characteristically hold to transverse courses. The way in which the greenstone limits the zone of diorite dikes, and the marked coherence of individual dikes to its lower surface, both point to the hanging-wall stratum as a controlling feature in the distribution of the diorite, and therefore suggest its earlier existence. The probability of this connection is well brought out by the map and cross section. Again, if the attitudes of the diorite dikes and the greenstone in reference to the slate country are compared, it is found that the diorite shows all the ordinary structural characteristics of intrusions, while the greenstone exhibits no features which necessarily require an intrusive origin. The diorite bodies change in shape from place to place, branch irregularly, crosscut the stratification locally, and include masses of slate. The greenstone is a single layer or bed which continues along the same horizon for at least 6 miles and shows but slight variations in thickness; it does not crosscut the slates, so far as observed, and it contains no slate inclusions. Under the circumstances it is strongly believed that the greenstone is not intrusive, but that it originated as a lava flow similar to many others in the same general series of alternating sediments and igneous rocks, while the diorite was intruded at a much later date.

BLACK SLATE.

The black slates, which constitute the main country rock near the Treadwell mines, belong to the third subzone of the slate-greenstone band already described. Together with the hanging-wall greenstone they constitute all of this subzone which appears on the southern half

of Douglas Island, the remaining portion being beneath Gastineau Channel. They are highly metamorphosed carbonaceous and calcareous shales, of fairly uniform texture; their stratification is usually determinable from variations in color and from slight changes in the character of material, and in so far as observed the bedding and principal slaty cleavage are always in accord.

The cleavage of the slates is regarded as having been produced before the diorite intrusions, the direction of which it largely controls. In this respect the secondary structure corresponds with that of the sedimentary rocks of the general region, all of which were tilted and metamorphosed before the diorites of the Coast Range were intruded. The slates are not altered by contact metamorphism next to the intrusive dikes of diorite.

ALBITE-DIORITE.

Classification of the Treadwell rock is somewhat difficult, because it has been impossible to procure entirely unaltered material. Doctor Becker, who first studied it with care, gave it the designation "sodium

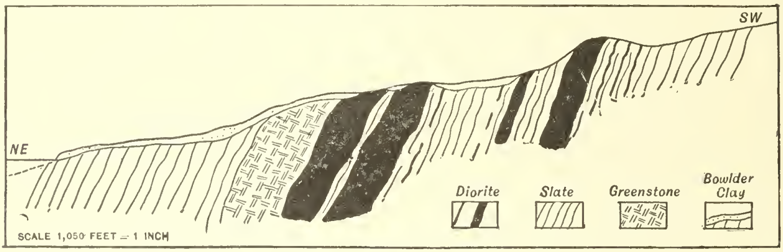

FIG. 2.—Cross section through Alaska Treadwell mine and northern side of Douglas Island.

syenite," to distinguish it from the ordinary syenites, which contain potassium as their alkali constituent. However, since the soda-feldspar albite, which is the characteristic mineral of the rock, belongs to the plagioclase series, and these feldspars are the distinguishing feature of dioritic rocks, he suggested the alternative name "albite-diorite," which is here employed because it indicates the known relationship of the Treadwell rock with the diorite intrusives of the adjacent Coast Range.

The rock varies in mineralogical composition from place to place, but it is always very much changed from its original condition. Most of it shows little or no ferromagnesian minerals, either because they were never present or because they have been decomposed and carried away by the mineralizing solutions which have permeated the rock. Specimens were collected, however, which contained hornblende in apparently original prisms, and biotite is sometimes observed. Secondarily crystallized mica and green hornblende are somewhat common, and with them a considerable amount of epidote is ordinarily found. Feldspar is present in two conditions, original and secondary.

The primary feldspars of the magma were albite-oligoclase, occurring in phenocrysts now always clouded by decomposition products, and microperthite with some pure albite, forming a granular groundmass of distinctly later crystallization. The composition of the phenocrysts is inferred in general from the presence of epidote as one of the minerals formed by the alteration of the feldspars, but this has been checked by the optical characteristics of relatively fresh material occurring in several specimens. The secondary feldspar is always albite, and is usually quite free from decomposition, and when it occurs in sufficient amounts it gives the rock a very fresh appearance. It seems to have been formed mainly at the expense of the original microperthite, which it replaces in part.

Quartz seems not to have been an original mineral in the albite-diorite, and it is never observed in the body of the rock associated with the secondary albite, but is confined to the veinlets which intersect the dikes. Calcite is common both in the veins and distributed through the rock itself along with the albite of the second generation.

Original accessory minerals noted are apatite, titanite, rutile, and magnetite. The secondary minerals which have been noted are uralite (secondary hornblende), green mica, chlorite, epidote, zoisite, calcite, quartz, sericite, rutile, pyrite, pyrrhotite, and stibnite, with other sulphides occurring exceptionally. Some of the magnetite seems also to have originated from the breaking up of former iron-bearing minerals, and where it surrounds cubes of pyrite it has apparently been deposited from the mineral solutions.

In the vicinity of the mines dikes of albite-diorite in the black slates are distributed throughout a zone about 3,000 feet in width, extending along the strike for 3 miles. Only bodies near the hanging wall of this zone have been mined up to the present time, though several others are strongly mineralized. The dimensions of the different dikes are extremely variable, the larger ones having a maximum observed width of over 200 feet in surface exposure and in the mine workings. From this all sizes occur down to the width of one's hand, and toward the ends of the intrusive area only small dikes occur, as may be observed along the bed of Bullion Creek.

Outside of the ground which has been worked, the details of the various diorite masses are unknown, but their general distribution is shown upon the geologic map, and the generalized cross section through the workings of the Treadwell mine indicates the relative number and size of the dikes which outcrop (figs. 1 and 2). Undoubtedly a still larger number, principally of small dikes, are hidden by gravel beds and by the deep mat of decaying vegetation which covers much of the ground.

In many cases—and this is particularly to be noted in the dikes which have been mined—the individual intrusions are made up of a series of

lenses formed by alternate bulging and pinching of the intrusive mass. In places the structure of the slate follows these irregularities, while elsewhere there is local crosscutting. Pinching and swelling of the diorite is shown in both vertical and horizontal cross sections of the dikes, though in general it is to be noted that the variations are more frequent and the changes take place within shorter distances upon the dip than upon the strike.

The greater frequency of the variations on the dip, which has been mentioned, may be due to faulting, for in the west end of the "Glory Hole" at the Treadwell mine, and in one or two other cases underground, where observations have been less readily made, the ore bodies are offset by movement along surfaces which strike nearly parallel to the veins, but dip at a lower angle. A series of such faults would produce the effect of alternate swelling and pinching (fig. 3).

Considerable work was done several years ago in prospecting adjacent bodies of diorite, many of which are as thoroughly impregnated with pyrite as the developed ore bodies. So far as known, the gold values are mostly very low; and while mines may yet be discovered, explorations have not thus far revealed workable ores.

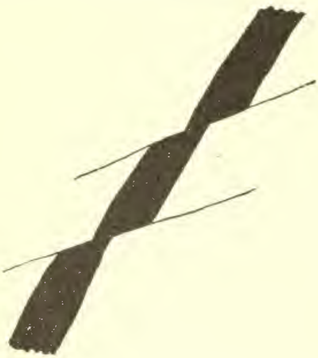

FIG. 3.—Ideal sketch showing manner in which faults of low dip may displace an inclined dike, giving appearance of alternate swelling and pinching.

The occurrence of the sulphide-bearing diorite which forms the Treadwell ore deposit has been described by Dr. G. M. Dawson, who visited the mine in 1889. This geologist believed the deposit to represent the upper portion or "feather edge" of a granitic intrusion, probably contemporaneous and connected with the granites of the neighboring Coast Range. The structural relations presented by this view are entirely in accord with present observations, for while the rock can not be strictly classed as granite, neither can a large part of the rocks which form the core of the Coast Range be so classed, since their composition is usually dioritic. The diorite of the Douglas Island mines doubtless belongs to the Coast Range period of intrusion; and if the small dikes of basalt which are found from place to place throughout the region be excepted, it is the youngest of the bed-rock formations in the vicinity. At the time of its intrusion the rocks which now appear at the surface occupied a position deep within the shell of the earth (lithosphere); and while many masses of the Coast Range diorite were forced through to the surface, it is doubtful whether any of these particular dikes ever extended as far as the surface which then existed. Taken together they represent intrusive material which was arrested en route, while larger masses of related rocks in the region are

regarded as the once deep-seated portions of intrusions which probably had actual surface exit. In the underground workings the blind endings of certain of the dikes show that some of them do not extend even to the present surface. How much farther the larger ones may have penetrated the slates now removed by erosion can not be estimated.

BASALT DIKES.

In several places in the mine workings there are basalt dikes, which cut all the other rocks. They are narrow, usually from a few inches up to 3 feet in width, and have sharply defined walls. Locally, the dikes occur in pairs, and in several places are seen to divide, particularly when they occur in zones of sheeted rock. The fissures in which they occur are transverse to the strike of the rocks and trend from N. 10° W. to about north and south, true meridian, with a rather steep dip toward the west. As a rule, they are not mineralized to any important extent, though a small amount of pyrite sometimes appears, and occasionally they contain a considerable amount of this mineral. In several places veinlets of calcite occur along the selvage, but these are readily determinable as of later orign than the greater part of the quartz and calcite which form a reticulation throughout the mass of the ore material.

THE ORES.

GENERAL DESCRIPTION.

The ore of the albite-diorite dikes consists mainly of rock impregnated with sulphides, principally pyrite, in part shattered and filled by reticulating veins of calcite and quartz, which also carry sulphides. The ore-bearing dikes are considerably mineralized throughout, and often the whole mass can be mined. Locally, however, the values are too low to pay for extraction, and portions of the rock must be left.

Three sorts of ore are recognized by the miners, "quartz," "brown ore," and "mixed ore." The so-called quartz ore, which constitutes the bulk of the workable material, is essentially mineralized diorite, but it usually contains calcite and quartz, the calcite disseminated or in veins, the quartz only in veins. As a rule, it is white or light gray, but in many places it has a greenish cast. The brown ore is derived from a comparatively small amount of productive mineralization occurring in the walls or in the narrow horses of slate, where the presence of gold-bearing sulphides is commonly recognized by a brown color, which leads to the popular designation of this ore. The brown material grades into the ordinary black slate, and its color is apparently due to decarbonization of the carbonaceous rock by percolating sulphide solutions. Impregnation of the slate is by no means general, and where it occurs it seldoms extends for more than 2 or 3 feet from the walls of the main ore mass. The mixed ore, which is more abundant

than the brown, is composed of slate intricately intruded by small dikes of very fine-grained diorite, the whole being impregnated with sulphides in the same way as the ordinary ore.

The value of the material mined varies from $1 to $5 and even $10 or more per ton, though in the course of development a great deal of less valuable rock is extracted, and in working the open pits large amounts of worthless slate must be moved, much of which goes with the ore to the stamps. In general the average value of the rock has been a few cents over $2 for the past two or three years. From 60 to 75 per cent of the gold is free milling, and the concentrates, which the mill records show to be about 2 per cent of the material treated, assay from $30 to $50 per ton.

SHAPE OF THE ORE BODIES.

The impregnation of the dikes in which the ore occurs is, for the most part, so general, and the presence of at least small amounts of gold is so constant, that it is impossible to recognize any well-defined masses which may properly be distinguished as ore shoots. Though the values are by no means uniformly distributed, from the assay plan they do not appear to occur in any regular way, and indeed the distinction between ore and rock too lean to pay for extraction is often the matter of only a few cents. The actual differences in gold tenor of several contiguous samples taken from the ore are usually much greater than the difference between the average of any considerable block of ore and the contents of intervening masses of poor rock. In several places mere joints or seams may be noted separating the ore and the poor material, and it frequently happens that blocks of the latter, which show assays from a trace up to $1, are entirely surrounded by ore averaging $2 or more. Structural limitations, such as joints, however, are difficult of observation, because the sides of the drifts are everywhere covered with dust.

In general, the best ore is that which contains the greatest number of quartz and calcite veinlets, and though their absence is not an infallible indication of valueless material, it seems that the irregular distribution of the gold has resulted mainly from original differences in the amount of crushing and the consequent varying permeability of the rock. Where the metasomatic replacement of the diorite by secondary albite is absent, the sulphides usually replace such minerals as hornblende or mica, and it is suspected that in these cases the gold content is ordinarily low.

In planning the position of stopes the assay charts often enable the miners to locate the pillars in relatively poor material, but as a rule the low-grade rock is not found to persist for the whole distance between two mine levels. The largest masses, which have been left because of their leanness, are on the foot-wall side of the south dike

in the Treadwell workings, but even here there are great variations in the gold tenor at different places. On the 110-foot level all the rock was minable; on the 220-foot level from 10 to 40 feet of low-grade stuff was left on the foot, excepting for a distance of about 150 feet. On the 330-foot level good values were found up to the slate, excepting for 200 feet along the west end, where 20 feet or so were left, while on the 440-foot level not over half of the rock gave assays over $1.

PERSISTENCE IN DEPTH.

The ore dikes have been developed along the dip for a distance of approximately 1,000 feet in all three of the mines now operated. The Treadwell workings reach about 700 feet below sea level, the Mexican 600 feet, and the Ready Bullion 800 feet.[a] In no case has it been possible to make out any progressive change in the character of the ore as depth was attained. The assay charts show the ore in the lowest levels to be as good as in the upper workings, and it is evident that variations along the dip are not greater than those observed from place to place along the strike. It is true that the mine records for a period of years show a gradual decrease in the per-ton value of the material which has been treated. This is especially noticeable in the case of the Treadwell mine, which has been the longest in operation, but it is the result of increasing the tonnage by mining low-grade rock rather than an indication that the average value is decreasing with depth.

It seems fair to assume that the ore will continue to at least a considerably greater depth without important change in average value. There is nothing in the character of the ore to indicate any important secondary concentration of values by oxidizing waters near the surface. On the other hand, the characteristics of the deposit are believed to indicate that it was formed in its present condition by the direct action of ascending waters. If this idea is correct, there can be little doubt that the mineralization and the values will continue to a much greater depth than has been reached, and it may be reasonably expected that the limit of deep mining will finally depend more upon increasing costs of hoisting and pumping than upon the exhaustion of the ore.

VEINING IN THE ORE BODIES.

In almost all parts of the Treadwell deposit reticulating veinlets of calcite and quartz are prominent features of the mineralized dikes. The veinlets are often composed entirely of calcite, but this mineral is usually accompanied by quartz, though the latter seldom, if ever, occurs by itself. The veinlets are rarely more than a few inches in width; many are only a fraction of an inch across, and

[a] October, 1903.

the microscope shows the presence of minute fracturing between the veins visible to the naked eye. The veins are usually closely spaced, and an estimate based on a study of all the mine workings indicates that infiltrated materials make up nearly one-fifth of the mass of the ore.

The boundaries of the veinlets against the inclosing rock are sometimes distinct, but in many cases there is an apparent gradation from the vein matter into the altered diorite. When the amount of introduced minerals is large in proportion to the mass of the matrix, in small specimens it is often difficult to distinguish the vein stuff from the rock, though in large fragments or on the stope faces, the general extent of the different portions of the ore material is exhibited. The microscope shows that the merging of the interstitial veinlets with the rock which they cut is due to penetration of the latter by calcite, which is intercrystallized with secondary albite, formed at the expense of the original feldspar.

Veinlets traverse the rock in different directions, but the greater part of the filling occurs in fissure-like openings constituting two well-marked systems. One set of fractures strikes and dips approximately with the structure of the inclosing slates; the other, which is the more prominent, strikes somewhat obliquely to the structure of the country rock and dips in the opposite direction—that is, toward the southwest.

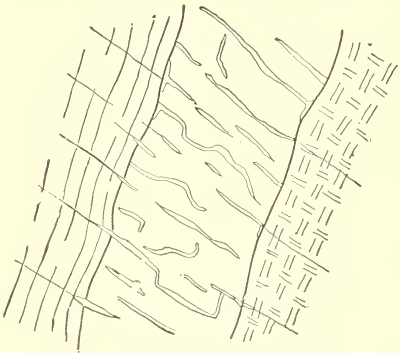

FIG. 4.—Dike of albite-diorite in open cut of Ready Bullion mine.

In places where the mineralized dikes are narrow, the set of fissures parallel to the country rock structure usually diminishes in importance and often only the cross fractures have been developed. This may be explained upon the supposition that the tendency to motion parallel to the walls of the intrusions was taken up outside of the massive rock in the slates, while the transverse strain affected both the slate and the intrusive rock, the latter being specially susceptible to cross fracture because of its small mass and brittle nature. Cross fractures, filled with vein stuff and limited to a narrow dike in the slates, may be seen to good advantage at the east end of the Ready Bullion pit, near the southernmost outcrop of the diorite (fig. 4). Throughout the mines it is the rule that all transverse gash veins stop at the walls of the diorite, and while there are a few exceptions the quartz seldom penetrates the country rock to any great distance, and when it does it diminishes rapidly in thickness. However, this is not always due to the nonpersistence of the fissures, for they may be frequently observed continuing from the diorite into the slate in the form of well-marked joints.

GANGUE MINERALS.

Feldspar, calcite, and quartz are the three important nonmetallic ninerals of the Treadwell ores. Part of the original feldspar of the ntrusive diorite remains in the ore, and with a considerable amount of secondary feldspar forms the principal gangue mineral. Other min- rals of the unaltered rock were hornblende and mica, but these are present in relatively small amounts, as is epidote, which has been formed as a product of alteration from them. Calcite and quartz occur in veinlets penetrating the diorite, and make up perhaps one- ifth of the material which is mined. Calcite is also found dissemi- nated irregularly in the more altered parts of the diorite, unaccom- panied by quartz. When sulphides and calcite are both present, they are almost invariably in contact with each other, but the secondary eldspar also carries a great deal of pyrite.

The occurrence of ferruginous calcite is common in the superficial vorkings, where it may have been formed by the action of iron-bear- ng solutions upon the primary calcite of the deposit. It occurs also n small amounts in deeper parts of the mines, where it is possibly an riginal mineral. A small amount of pink carbonate, probably a nixture of calcite and rhodochrosite, has been observed in the open pits of the Ready Bullion.

METALLIC MINERALS.

As shown by the mill records, the metallic minerals, or "sulphides," onstitute about 2 per cent of the Treadwell ores. They consist mainly f iron pyrites, but a considerable amount of magnetite is also present. Pyrite occurs both in the rock and in the veinlets, but the position f the sulphides has no apparent influence on the gold content. In he rock it invariably has the form of minute cubes, ranging from a size carcely visible to the unaided eye up to about one millimeter, rarely arger. It is distributed sparsely through the diorite accompanying he secondary minerals, especially the albite and calcite, though where hese are not present it is associated with epidote and uralitic horn- lende. In the reticulating veinlets the pyrite occurs either as sepa- ate cubes, often several millimeters across, or in bunchy aggregates, orming "turkey-egg rock," which usually contains more than aver- ge values.

Magnetite occurs only in the form of minute grains outside the einlets. Part of it appears to have been an original constituent of he diorite, but much of it was deposited secondarily along with the yrite, perfect cubes of which it sometimes surrounds.

Rutile occurs in minute needles, and though seldom visible to the aked eye the microscope shows that it is widely distributed in various arts of the mines. As a rule, it occurs embedded in calcite, but it is ometimes in the secondary albite. Pyrrhotite often accompanies or

takes the place of the pyrite and may be readily isolated from the concentrates by means of a magnet. Chalcopyrite, galena, and sphalerite occur sporadically, and native arsenic, realgar, and orpiment have been noted in small quantities. Assays are said to indicate the arsenical nature of much of the pyrite, though the presence of true arsenopyrite has not been recognized. Molybdenite is frequently noted, though it is irregularly distributed.

OCCURRENCE OF GOLD.

Visible gold has been observed in veins of coarsely crystalline calcite inclosed in the ore bodies. This occurrence is, however, rare, and in general even the microscope does not reveal the form in which the precious metal exists. I have not been able to distinguish gold in the thin sections studied under the microscope, but Prof. F. D. Adams, who examined the material collected by Dawson in 1887, observed gold mechanically inclosed in crystals of pyrite. It is evident that a considerable amount of gold must be in the metallic condition, because a large proportion is saved by amalgamation, the amount sometimes being as high as 75 per cent of the total assay value.

The gold is perhaps mainly associated with pyrite, but rather coarse crushing is the present mill practice,[a] and so much of the pyrite passes the screens in comparatively large grains or unbroken crystals, that it seems open to doubt whether from 60 to 75 per cent of the gold could be free-milling if it were all associated with the iron sulphide. The nonamalgamating portion undoubtedly does occur with the pyrite, because the concentrates contain only pyrite and magnetite, with a small amount of pyrrhotite, all the molybdenite going into the tailings. Molybdenite can hardly be an important carrier of gold, because it seems to be somewhat limited in distribution, although its presence in visible quantities is said to indicate high values.

As a rule, the values vary with the amount of interstitial vein matter, but the position of the pyrite in the rock or in the quartz and calcite seem to have no influence upon the amount of gold. In some places, where the ore is of average grade, all the metallic minerals seem to be in the rock, and careful search is necessary for the discovery of any sulphide in the quartz or calcite. Elsewhere the sulphides may be confined almost entirely to the veinlets. A limited amount of material is mined which contains practically no stringers of quartz or calcite, the sulphide being disseminated through the mass of the rock—for instance, in the crosscut on the 440-foot level and in stope No. 1 of the 330-foot level in the Treadwell mine. In other places material of similar appearance, containing an equal amount of pyrite, yields only a very small amount of gold.

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[a] Slot screens equivalent to 18- and 20-mesh wire screens are used.

METASOMATIC ALTERATION.

As already stated, the Treadwell ore bodies are dikes of albite-diorite filled with reticulating veinlets of quartz and calcite and permeated with metallic sulphides carrying small amounts of gold.

From the structure of the deposits it is evident that the dikes were subjected to pressure which caused fracturing, whereby they became porous, affording channels of easy circulation for underground waters. The minerals in the ores and their mutual relations suggest that carbonated and mineral-bearing solutions found the broken dikes and continued to move through them for a very long period. In transit these waters attacked the minerals of the albite-diorite, decomposing them, and in some cases effecting more or less complete metasomatic replacement. As a rule, the hornblende and mica of the original rock have entirely disappeared, their place being taken by aggregates of secondary minerals, sometimes including metallic sulphides. A few specimens of relatively unaltered material indicate that the original rock characteristically contained two sorts of feldspar, albite-oligoclase, and microperthite. The first occurs in phenocrysts of fairly definite form, often showing concentric structure, and always clouded by decomposition products, excepting for clear rims, which are usually narrow. The microperthite, which has the characteristic mottled appearance of this minute intercrystallization of albite and orthoclase, is entirely interstitial as regards the albite-oligoclase. It is usually nearly free from decomposition inclusions, and is ordinarily accompanied by some clear albite. When pyrite occurs in such slightly altered material it lies in or next to decomposed hornblende crystals. Most of the rock has suffered extreme alteration, and pyrite occurs throughout interstitial groundmass. Its introduction has apparently been accompanied by breaking down of the microperthite, for this mineral, so abundant in the comparatively fresh rock, is usually entirely absent when the sulphide occurs outside of the decomposed hornblende—that is to say, in the interstitial feldspar. In the most altered rock the place of the microperthite is taken by an aggregate of small albite crystals, and this mineral is regarded as a secondary replacement of the original feldspar. In some cases the replacement has gone so far that the crystals of albite-oligoclase have been attacked. This feature is relied on in part to prove the secondary nature of the albite, but more conclusive evidences that the albite is of secondary origin are its occurrence in veinlets cutting the old feldspar, the fact that it is found intercrystallized with calcite, both in veinlets and throughout the rock itself, and the fact that where albite forms the interstitial material instead of microperthite, pyrite, and often rutile, are present, embedded either in the feldspar or in the evidently contemporaneous calcite.

The alteration of the Treadwell diorite is regarded as a phenomenon which accompanied the formation of the veinlets which intersect the rock, and the metasomatic action is attributed to the same solutions as those which deposited the quartz and calcite. The minerals last named appear to have been for the most part introduced, but the albite is believed to have been formed entirely, or nearly so, from the previous minerals of the diorite, because it is not found in the larger vein-fillings. It is commonly observed that where both calcite and quartz are present in the fractures, the former usually occurs next to the walls, and it always permeates the rock to a greater or less extent.

According to Lindgren, alteration of the sort here described has not been previously recorded, for though albite occurs as a vein mineral in California, it has not been detected among the metasomatic minerals in the wall rocks of veins.[a] In this connection, however, reference should be made to pseudomorphs of albite after adularia from St. Gotthard. These are described by Bischoff,[b] who gives an extended discussion of the probable chemical reactions involved, and suggests the competence of waters containing sodium chloride to effect the observed replacement of potash feldspar by soda feldspar.

The occurrence of values in the wall rock to such an extent as is observed in the Treadwell ores is also somewhat unusual, though not unique.

RÔLE OF THE BASALT DIKES.

In his discussion of the genesis of the Treadwell-Mexican ores, Doctor Becker leaves some doubt as to the importance which he desired to assign to the basalt dikes as mineralizers. He first says that the genesis of the ores is probably connected with the dikes, but afterwards suggests the relative unimportance of their influence.[c]

In the Treadwell and Seven Hundred Foot mines, two narrow dikes of the basalt are observed in a zone of sheeting, which is undoubtedly later than most of the veinlets in the ore mass. A small amount of calcite is found along their selvages, but they contain little or no pyrite. Upon the west or hanging-wall side of the dikes the ore is somewhat richer than it is between and beneath them, but it seems that this variation in gold tenor can not be attributed to the dikes as mineralizers, because the rock between them is not enriched, as might be expected had they been an actual source of gold. Possibly a rearrangement of values by relatively recent circulation has been going on, and the course of the currents may well have been controlled by the zone of sheeting in which the dikes occur, but secondary migration of this sort must be distinguished from the original mineralization, the extensive results of which in the neighborhood are entirely

[a] Lindgren, W., Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, p. 533.
[b] Chem. Geol., vol. 2, pp. 409-411.
[c] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 69.

eyond comparison with the effects directly or indirectly attributable o a pair of narrow dikes of this sort. It is now believed that they ave no connection with the formation of the ore.

Other basaltic dikes occurring in Gold Creek, near Juneau, are egarded as practically of the same age as those on Douglas Island, nd these are also unmistakably younger than the gold-bearing quartz eins of that neighborhood.

ORIGIN OF THE FRACTURES.

Upon the fracturing of the Treadwell dikes their impregnation with old-bearing sulphides is evidently dependent. The systematic arrangenent of the reticulating veinlets in two main sets standing at right ngles to each other and dipping in opposite directions led Becker to he conclusion that the fractures had been produced through comressive shearing stresses. He suggested that these stresses were aused by nearly tangential forces acting in a direction normal to the ommon strike of the two sets of fractures, which is also approxinately the strike of the country rocks.[a] The fact that the fractures re due to compressive thrust need not be questioned, since the theory f the subject has been so ably developed and so fully corroborated y experiment.[b] Some doubt arises, however, as to the direction in hich the forces may have been applied, because the geologic history f the general region since the diorite intrusions seems to indicate hat no widespread lateral compression has taken place. If tangential hortening has been going on, evidences of the fact, independent of he fracturing, has not yet appeared. On the other hand, a study of he wide physiographic features of this portion of North America has hown that a succession of continental uplifts has taken place since he period of the diorite invasion, and it seems necessary to suppose hat such radial movements would tend rather toward areal dilation han toward contraction, as in the opposite case of tangential comression.[c]

It is suggested that the general fissuring throughout the Juneau istrict may have been caused by gravitative adjustment in the ock masses, tending to restore internal equilibrium disturbed during he uplifts which are known to have taken place. The rocks of the istrict consist of alternating beds of greatly varying physical charcter, and they possess an eminent cleavage structure parallel with he stratification. Under stress such rocks would yield more readily long the preexisting structure planes than in other directions. That his old structure has, in fact, taken up most of the internal movenent during the later deformation of the rocks is evident from the

[a] Becker, G. F., op. cit., p. 67.

[b] Becker, G. F., Finite homogeneous strain: Bull. Geol. Soc. America, vol. 4, 1893, p. 13. Daubrée, tudes Synthetique de Geologie Experimentale, p. 316.

[c] Spencer, A. C., The Pacific mountain system in British Columbia and Alaska: Bull. Geol. Soc. merica, vol. 14, 1903, pp. 117-132.

occurrence of so large a majority of the veins in parallel position with it, and it may be supposed that this control has prevented the formation of a large number of fissures in various directions, which would have resulted in the case of homogenous or massive rocks deformed under their own weight.

Having been subjected to the same pressures as those which fractured the other rocks of the region, it is only natural that the Treadwell dikes should be broken along lines parallel with the general fissuring, and one of the two sets of veinlets occurring in the ore bodies practically coincides with the structure of the inclosing slates. The other set, which stands at right angles to the first, is not nearly so well developed in the country slates, probably because these yielded by bending, since they are very flexible when compared with the brittle rock of the dikes.

SOURCE OF THE VEIN-FORMING WATERS.

The formation of the Treadwell ores is assigned to the same general cause as the other veins of the region. Both are attributed to circulating waters moving through channels opened by a general fracturing of the rocks.

From the nature of the metasomatic changes which the waters have effected, and also from the large amounts of carbon dioxide which they evidently contained, it may be assumed that they were ascending.[a] That they were hot may also be safely predicated, because the erosional history of the region indicates that the veins now exposed must have been deposited at great depths, certainly not less than from 6,000 to 10,000 feet below the former surface and possibly very much deeper. The occurrence of tourmaline in some of the veins of Gold Creek, and the occasional presence of fluorite elsewhere, suggests a connection with igneous emanations, for these minerals are characteristic of pneumatolytic action, as exhibited in the case of tin deposits and in various instances of contact metamorphism. The presence of these minerals can not be pushed to the value of evidence because neither of them have been universally observed in the district, but, even for those who hold the theory that the final source of mineralizing water is mainly meteoric, their occurrence may be admitted as probably significant of at least accessory contributions to the vein-forming solutions from igneous sources.

It is concluded that known facts do not lead to a recognition of the actual source of the solutions which have formed the mineral deposits, and any present idea of their origin must rest largely on speculation. I am inclined to believe that the very wide occurrence throughout southeastern Alaska of intrusions related to, and of practically iden-

[a] Lindgren, W., Gold-quartz veins of Grass Valley district, California: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, p. 173.

ical date with, the Coast Range diorites strongly indicates the possi-
ility of a great buried *couche*, or reservoir, of igneous rock under-
ying the whole region. It is evident throughout the field that the
eins were formed at a period subsequent to the invasion of the
iorite, and they were probably formed long after intrusion had
eased, but it is not a violent supposition to consider that the deep-
eated magma from which the masses now observed at the surface
ad been given off remained in a molten condition for a very long
me.

A plausible hypothesis for the formation of the veins, based upon
ie foregoing ideas, is that the unknown forces which at various
mes have caused general elevation throughout the region were trans-
iitted by this great residual magma to the overlying rocks. In
djusting themselves to the changed conditions of equilibrium, the
ocks were fractured; then, as the deep-seated magma gradually cooled
nd crystallized, water and gases expelled from it found their way into
ie overlying rocks, and, searching out the easiest routes of travel
long existing fractures, escaped to the surface. Undoubtedly waters
f this origin might carry in solution all the elements which have been
bserved in the veins, and they would deposit their mineral contents
nder various conditions, such as decrease of dissolving power through
iminishing pressure and temperature, precipitation through metaso-
iatic interchange with wall-rock materials, or precipitation due to
iingling with solutions of some other derivation.

SUMMARY.

The large bodies of gold ore in the Treadwell mines are secondarily
iineralized dioritic dikes lying between a hanging wall of greenstone
nd a foot wall of black slate. The gold accompanies pyrite and other
ilphides occurring both in reticulating seams of calcite and quartz
nd disseminated through the rock itself.

Feldspar remaining from the original rock consists of oligoclase and
iicroperthite, but these have been largely replaced by albite through
ie metasomatic action of the vein-forming waters.

The veinlets occur in two sets of fractures at right angles to each
ther, which were probably produced by shearing stresses incident
pon continental uplifting. Hot ascending solutions, possibly of mag-
iatic origin, have been the cause of mineralization, and the evidence
in favor of only one period of concentration.

Secondary concentration of the metallic minerals being absent, there
no reason to anticipate any decrease in the per ton value of the ores
greater depths are attained.

THE CAPE YAKTAG PLACERS.

By George C. Martin.

INTRODUCTION.

The occurrence of gold in the sands of the ocean beach near Cape Yaktag has been known and the deposits worked intermittently for several years. The locality began to attract considerable attention during the winter of 1903–4, since which time about 200 people have been on the ground more or less continuously. The amount of production during this time is not definitely known, for no record has been kept, and all estimates vary widely. The best estimates give a total of $10,000 or $15,000 for the past year.

It may be noted that neighboring and possibly similar placers have been worked at a profit on a small scale at Yakutat Bay, Lituya Bay, and Icy Cape; but attempts to work on a larger scale have not been successful.

Cape Yaktag is about 75 miles east of Controller Bay and 400 miles northwest of Sitka. The shore from Yakutat to Controller Bay is unbroken and there is no harbor which affords shelter even for a small boat. A strip of land from 5 to 10 miles in width lies between the coast and Bering Glacier. The ice front is marked by a line of hills, which are parallel to the coast and from which a steep slope descends to the sea. This slope is drained by many short parallel streams, some of which head in the ice. The gold-bearing beach is said to extend eastward for about 15 miles from the mouth of Yaktag River, which is the easternmost of the longer streams reaching the ocean near Cape Yaktag.

The region may be reached either by landing from a steamer through the surf, which can be done only in good weather, or by a difficult foot journey along the beach from Kayak. The latter is practicable only when the streams are frozen or when a light boat is carried. A favorite method is to drag a light canoe along the beach on a small cart. Cape Yaktag can be reached from Okalee Spit, in Controller Bay, by this method in two days. Three steamers stop at Kayak each month throughout the year. This region has not been visited by any member of the Geological Survey, and the following information is compiled from various sources. Most of it is believed to be reliable.

GEOLOGY.

The rocks are said to consist of shales with interbedded sandstone and limestone, and to resemble very closely in lithologic character

some of the rocks of the Controller Bay region. They carry Miocene fossils. The structure, it is said, is anticlinal, with the axis parallel to and very near the shore line. The dip on the southern flank of the fold is very steep, the rocks being practically vertical along the beach. The dip on the northern flank is much gentler, seldom exceeding 20°. The northward dip continues inland as far as the region has been explored. The structure is very uniform, no marked variations from the strike and dip recorded above having been noticed. There is said to be a belt of crystalline rocks inland at the base of or in the St. Elias Range.

OCCURRENCE OF GOLD.

The gold is found in the sands of the ocean beach and generally occurs in small amounts, richer patches being irregularly distributed. The creek gravels are said to be barren except at the mouths of the creeks where they have been affected by the ocean waves. Garnet sand carries the gold, which is for the most part very fine. Occasional 25-cent nuggets are found and a very few of the value of several dollars have been reported.

The men can make small wages at all times, if not too crowded, while after each heavy storm rich sands are always found. The old ground can be worked over anew after each storm, but whether this is due to new concentration by the ocean waves or to the exposure of unworked material is not known. The deposits can be worked all winter; in fact, more gold is found after the severe winter storms than during the summer when storms are less frequent and less severe. The gold has been obtained by rockers, sea water being largely used.

Attempts to work the gravels underlying the tundra on the edge of Bering Glacier are said to have been unsuccessful.

The gold was probably concentrated by wave action from the morainal material brought to the coast by the Bering Glacier.

Unaltered Miocene rocks on the coast are not known to be auriferous in this or other districts, hence the original source of the gold is doubtless in the metamorphic or other crystalline rocks of the St. Elias Range.

Some beach sands from Yakutat Bay have been studied by Mr. J. Stanley-Brown,[a] who found the sand to be "made up of grains of gold, magnetite, garnet, hornblende, pyroxene, zircon, quartz, feldspar, calcite, and mica, associated with fragments of a shaly, slaty, and schistose character." He concludes that the sand was doubtless derived from the destruction of metamorphic rocks.

It does not seem likely that the region will ever become of great importance, for the gold is very finely disseminated in all glacial deposits, and the zone of wave concentration is small.

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[a] Nat. Geog. Mag., vol. 3, 1891, pp. 196-198.

THE GOLD PLACERS OF TURNAGAIN ARM.[a]

By Fred H. Moffit.

GENERAL STATEMENT.

The region adjacent to Cook Inlet, Alaska, first came into prominence as a producer of placer gold in 1896. The presence of gold in some of the gravels was, however, known to a few prospectors and traders previous to that time, and some attempts at mining had been made many years before by the Russians. In fact, the first report of gold in Alaska was made by the Russian mining engineer, Doroshin, who conducted an examination of the mineral resources of Cook Inlet for the Russian American Company in 1848. Remains of old Russian workings and tools have been found in one or two places, but active mining operations seem to have been discouraged by the fur companies, which controlled the country up to the time of its purchase by the United States. A large part of the gold product of the Turnagain Arm region is due to the labor of miners who were without capital, who took out the richest and more easily mined deposits, and who have since left. The conditions under which mining has been carried on, therefore, make it impossible to give an accurate estimate of the amount of gold produced, but it is believed that the average yearly output since the opening up of the region is less than $150,000.

GEOGRAPHY.

Cook Inlet is the deep indentation that opens into the northwestern part of the Gulf of Alaska, and forms the western boundary of Kenai Peninsula, separating it from the base of the Alaskan Peninsula on the west. It extends in a direction nearly northeast and southwest for a distance of almost 170 miles, and is divided at its northeast end into two long, narrow branches known as Turnagain and Knik arms.

The first of these, Turnagain Arm, extends in an east-west direction, and is between 40 and 45 miles long. It forms part of the northern boundary of Kenai Peninsula, and reaches on the east to within 12 miles of Portage Bay, a western branch of Prince William Sound.

[a] This paper is an abstract of a more complete discussion of this district now being prepared for publication.

Turnagain Arm is characterized by remarkably high tides, beginning with a bore which has a height of 6 feet at times, and runs in from the inlet at a speed of 5 or 6 miles an hour. At low tide the arm becomes a broad mud flat, cut here and there by the stream channels. Small

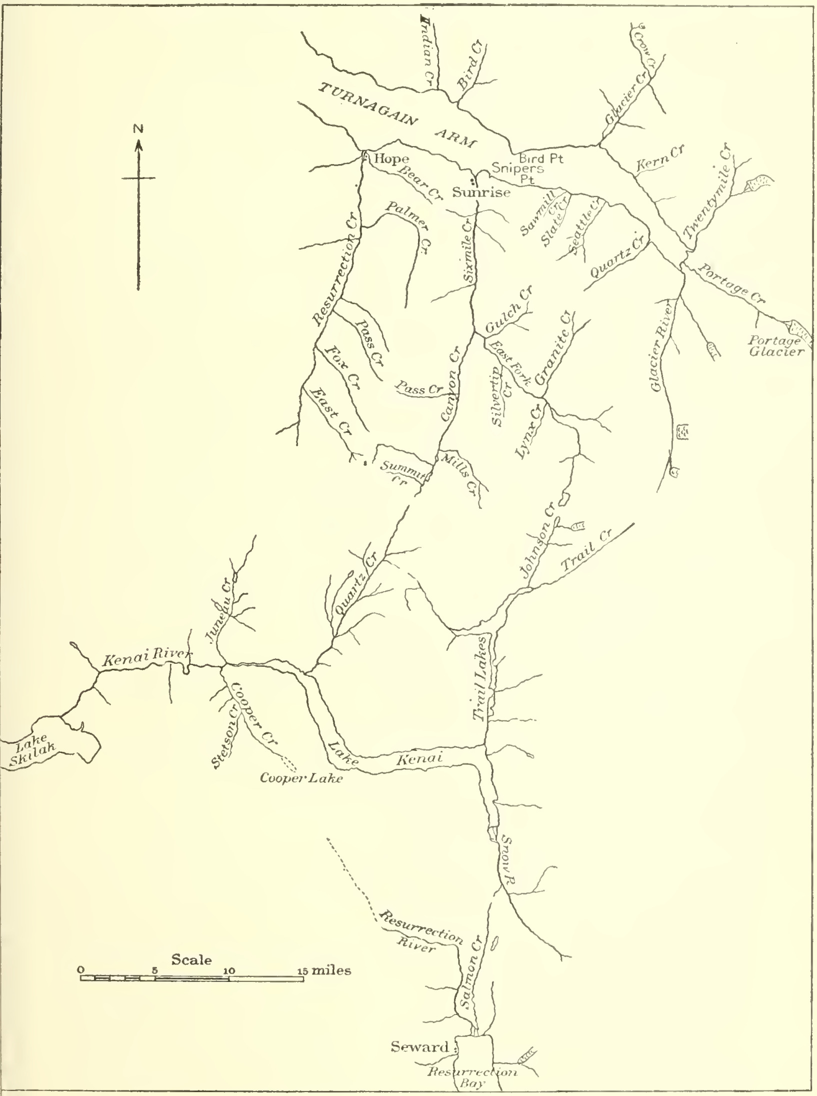

FIG. 5.—Sketch map of the Turnagain Arm placer region.

steamers enter and leave on high water, but the bore and swift currents make the use of small boats dangerous.

The productive creeks in the placer gold field here described are, with one exception, tributary to Turnagain Arm. The four most important of these are Resurrection Creek, Bear Creek, Sixmile

Creek, and Glacier Creek, with their branches. Resurrection Creek flows into the south side of the arm about 20 miles east of the main body of Cook Inlet, and with Sixmile Creek, 8 miles farther east, and its various branches, drains a large part of the northeastern portion of Kenai Peninsula. Resurrection Creek is a little more than 20 miles long, and flows in a direction slightly east of north. The town of Hope is located near its mouth. Palmer Creek is its largest tributary.

Bear Creek flows into Turnagain Arm one-half mile east of the mouth of Resurrection Creek. It is nearly 6 miles long, and follows a northwesterly course through a steep, narrow valley. Bear and Palmer creeks are the two producing streams of this part of the field and both are connected with Hope by good wagon roads.

The drainage area of Sixmile Creek is much larger than that of Resurrection Creek, and the stream is formed by the confluence of two large branches, which unite 10 miles south of Sunrise, the mining camp at its mouth. The larger of the two forks, known as the East Fork, is itself formed by the confluence of a number of small streams. The more important of these are Gulch and Granite creeks on the north and Lynx and Silvertip creeks on the south. The smaller fork, Canyon Creek, flows almost directly northward and, with its eastern tributary, Mills Creek, has been the chief producer of the Turnagain Arm field.

Glacier Creek enters Turnagain Arm from the north, 12 miles from its eastern end. The western branch of this stream, called Crow Creek, is the only tributary that need be mentioned here. The location of these streams will be better understood by referring to the accompanying sketch map, fig. 5.

In addition to the four principal streams above described, one other, Kenai River, should be mentioned, since some gold has been produced on one of its tributaries, Cooper Creek. Kenai River, the largest stream on Kenai Peninsula, empties into Cook Inlet. The upper part, known as Snow River, rises in the watershed between Resurrection Bay and Prince William Sound and empties into Lake Kenai. From the foot of Lake Kenai the river runs in a general westerly direction for 15 miles to Lake Skilak, whence it flows on again to the inlet, thus crossing the entire peninsula. The upper part of the river, from Lake Skilak to the source, lies in a country of rugged mountains, but the lower river flows in a winding course across a broad, marshy flat. Cooper Creek drains a small body of water called Cooper Lake. It is about 10 miles long and flows into Kenai River from the south, 3 miles below the Kenai Lake.

The region adjacent to Turnagain Arm is very rugged. Mountains rise precipitously on both sides of the arm and reach altitudes of 5,000 and 6,000 feet. Their tops are ragged and bare, for the timber rarely reaches higher than 1,500 or 2,000 feet. The smaller valleys are nar

row and steep, but the larger ones frequently show by their U-shaped cross section the former presence of glaciers. In fact, glaciers may be still seen at a number of places. Chief among them are Portage Glacier, occupying the pass between the head of Turnagain Arm and Portage Bay, and the two neighboring glaciers on Glacier River and Twentymile Creek. Besides these there are several smaller ones on tributaries of Glacier Creek.

The towns of Hope and Sunrise are the distributing points from which supplies of all kinds are carried to the creeks of the Turnagain Arm field. A small steamer, the *Tyonic*, connects with the larger ocean-going vessels at Seldovia, on the southern end of Kenai Peninsula, bringing mail and freight to the towns in the Cook Inlet region. This steamer makes no trips during the winter, for the ice prevents navigation in the upper part of the inlet during about five months in the year. It is customary to carry in supplies for the camps over the snow in winter, when traveling is far less difficult than in summer. The country is heavily timbered up to an altitude of 1,500 or 2,000 feet. This timber is chiefly spruce, but comprises a minor amount of hemlock, cottonwood, and birch. Spruce and hemlock reach a diameter of 20 inches or more and furnish some lumber for the purposes of the miner. One or two sawmills have been constructed to supply this demand.

The line of the Alaska Central Railroad, now in course of construction, runs northward from Resurrection Bay, by way of Salmon Creek, Snow River, Trail Creek, and Glacier River, to the eastern end of Turnagain Arm, then westward along the north shore to Knik Arm. It will not, therefore, reach the mining camps adjacent to Hope and Sunrise, but will furnish a much easier method of landing supplies on Glacier Creek than is now possible.

GEOLOGY.

The eastern portion of Kenai Peninsula and the region about the head of Turnagain Arm present a succession of rocks, which as a whole are of remarkably uniform appearance and composition. They are of sedimentary origin and consist chiefly of fine-grained gray and bluish-black slates and gray arkoses. Interstratified with these, but in far less amount, are quartzose beds and occasional thin conglomerates. In a few places north of Turnagain Arm this series of rocks, called by Mendenhall[a] the Sunrise series, is cut by dikes of igneous rock of an aplitic or granitic character. These igneous rocks were not found in the region immediately south of the arm, and while the bowlders of granitic material seen in the gravels might suggest the presence of igneous intrusions, it is believed that if intrusive rocks occur here at

[a] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1898, p. 305.

all they will be found only in rare dikes. The whole rock succession is closely folded, and the arkoses as well as the slates show cleavage, which is, however, much more perfectly developed in the slates.

In crossing Kenai Peninsula from Resurrection Bay on the south to Sunrise on the north it was found that, aside from local variations, the general strike of the Sunrise series ranges from about N. to N. 20° E. North of Turnagain Arm a decided difference was observed, for there the strike of the bedding varies from N. 45° E. to N. 70° E.

In that portion of the Kenai Mountains between Seward and Sunrise the bedding is often obscure, usually having the same strike as the cleavage. On the north shore of the arm, however, the bedding and cleavage frequently do not have the same strike, and where this is the case the cleavage on both sides of the arm corresponds more nearly in strike than does the bedding. Faults are frequent, but the amount of the displacement is usually difficult to determine.

Immense deposits of gravel occur at a number of localities, but are especially noticeable in the valleys of Sixmile Creek, Resurrection Creek, and Kenai River. The flat-topped benches have an elevation of nearly 1,000 feet above sea level around the lower end of Lake Kenai, and the same elevation was observed in the valleys of the streams mentioned. The bench gravels show a thickness of 100 to 200 feet in the upper valleys, where they have been cut through by the streams.

Evidences of a former period of glacial activity are seen on all sides in broad-bottomed U-shaped valleys, polished rock surfaces, and transported bowlders. The shores of Turnagain Arm afford frequent proof of ice action in glacial markings and striated pebbles. Hanging valleys are not uncommon. Rounded hilltops, over a thousand feet above sea level, on the north side of Lake Skilak, are beautifully smoothed and grooved, while the gravels of the lake shores contain an abundance of granite fragments. Such fragments are not found on any of the streams of the present drainage and must have come from some locality to the north. This glaciation is due in part to the action of small ice masses like those that now occupy the mountain valleys, but is perhaps in greater degree attributable to the movements of a far more extended ice sheet which reached down from the north.

GOLD.

Practically all the gold produced in the Turnagain Arm field is derived from creek gravels. In one or two places, however, attempts are being made to develop mines in vein deposits. The gold occurrences, therefore, will be classified and described as placer and lode deposits. In this brief account no mention will be made of streams that were not producing during the past season.

PLACER DEPOSITS.

The known placer-gold deposits of commercial value are confined geographically to three small areas, the valleys of Resurrection, Sixmile, and Glacier creeks. It may be said in general that the gravels are much alike in composition, are due partly to local erosion and partly to transportation by glacial ice, and contain a very large proportion of coarse material—rounded and angular blocks—which occasionally have diameters as great as 8 or 10 feet.

Pick and shovel mining has gradually given place to hydraulic methods, by which nearly all work is now carried on. During the past summer, owing to frequent rains and the gradual melting of the snow on the mountains, the water supply was abundant, and no complaints of water famine were heard. A head of 150 to 200 feet has been secured with little difficulty and expense on any of the creeks where mining is now carried on.

RESURRECTION CREEK DISTRICT.

Considerable mining has been done on Resurrection Creek itself, but at present the producing streams of the district are Bear Creek and Palmer Creek.

Bear Creek.—Bear Creek was first worked in 1894 and is therefore one of the best known streams of the field. It occupies a steep, narrow valley in the high divide between Resurrection and Sixmile creeks and joins Turnagain Arm just east of the town of Hope. The bed rock shows a succession of slates and arkoses, whose strike is nearly at right angles to the general course of the creek. The gravels consist chiefly of material like the bed rock, but contain some foreign matter, much of which is granitic in character. They are in general but poorly stratified.

The gold is associated with a small amount of native silver. It is coarse and smooth and of lower grade than any other of the Resurrection district. The best pay is from bed rock, which is sometimes a glacial clay. One nugget worth over $200 was found.

Mining is confined to the stream bed and until the last two years has been carried on chiefly with pick and shovel. At present there are two hydraulic plants on the creek, only one of which was working during the season just ended.

Palmer Creek.—Palmer Creek, the largest tributary to Resurrection Creek, is the only one that produced any gold during the last season. The upper stream flows through a broad valley, while the lower portion occupies a narrow, box-like canyon cut partly in rock and partly in the gravel terraces of Resurrection Creek. Most of the mining is done along the lower canyon portion of the valley. The bed rock is largely grit (arkose) interbedded with slates and is very much jointed.

The gravels now being worked do not differ in any marked way from those of Bear Creek, excepting that they seem to contain a smaller percentage of granitic bowlders and other foreign material. The lower gravels are partly stratified.

Palmer Creek gold is coarse and heavy, usually much flattened and smooth, and passes at $16 per ounce at the stores. Pieces of silver weighing as high as one pennyweight were seen, and a small amount of black sand is also found in the boxes. Two hydraulic plants were in operation during the summer, but their efficiency is not great owing to the large number of bowlders which can not be handled by the pipe and must be removed by hand. Probably less than 100 yards a day are moved by either of these plants.

SIXMILE CREEK DISTRICT.

Sixmile Creek, while only a few miles east of Resurrection Creek, is cut off from it by a high ridge which can not be crossed without great difficulty, except in a few places. The chief producing streams belonging to the Sixmile drainage system are Canyon Creek and its eastern tributary, Mills Creek.

Canyon Creek.—Throughout the greater part of its length Canyon Creek, the south fork of Sixmile Creek, flows, as its name implies, in a deep, narrow canyon. This canyon cuts through rock as well as gravel and is over 100 feet deep in many places. It is plainly a young feature of the topography and not the original channel of the stream that drained the upper valley.

The bed rock consists of slates and arkoses. The gravels are of like composition, and in places on the benches have been consolidated into a hard conglomerate, known locally as "cement gravel." Few granite bowlders were seen in the Sixmile region.

The stream gravels, which are the principal ones worked, are shallow. The gold values are taken from bed rock and are often concentrated in rich pockets, where they were deposited in eddies and more quiet stretches of the water.

Canyon Creek gold, especially in the lower part where it joins the East Fork, is finer than that from Bear and Palmer creeks and is of higher grade, assaying over $17 per ounce.

The narrow channel and swift current makes the ground difficult to handle. Wing dams are necessary in all cases and are liable to be carried away in time of high water, an accident not uncommon during the days of greatest mining activity on the stream. At present one hydraulic plant is at work on bench gravels above the stream and a second is working ground near the mouth of Mills Creek.

Mills Creek.—Mills Creek was the first stream staked in the Sixmile region. It joins Canyon Creek 8 miles south of "the forks" of Sixmile Creek and drains a portion of the high mountainous area east of Canyon Creek.

That portion of the creek which has been most productive lies in a narrow canyon, three-quarters of a mile long, extending from the mouth of the stream to Juneau Creek. The bed rock and gravels are similar to those of Canyon Creek, and high gravel benches are also present here. The creek bed through the canyon has been largely worked over and has afforded a considerable amount of gold, making this stream second to Canyon Creek in production. In places, in addition to the loose deposits, a hard "cement gravel," containing gold, has been formed, but has not yet been very successfully worked by hydraulic methods because it is difficult to break up. The gold in the "cement gravel" is flattened and considerably finer than the coarse, heavy gold found on bed rock. Nuggets worth several dollars are not uncommon in the coarser gold, and sometimes show striations, as if they had been dragged over a rough surface. All mining, till within the last two years, was done by hand, but at present a hydraulic plant, employing only natives as laborers, is in operation near the mouth of Juneau Creek.

GLACIER CREEK DISTRICT.

Crow Creek.—Crow Creek, on the north side of Turnagain Arm, is a tributary of Glacier Creek. It is a short stream, 4 or 5 miles long, and receives part of its waters from the melting ice of one or two small glaciers in the high mountains at its head. The central part of the stream occupies a broad, rounded valley, but the lower part flows, in a series of rapids and waterfalls, through a narrow canyon. The valley of Crow Creek is plainly the bed of an old glacier, whose retreat left the valley floor strewn with a mass of débris brought down from the mountains above. The bed rock is made up of slates and arkoses. The gravels are of the same material, but contain in addition a large amount of granitic rock. Enormous bowlders have been deposited in the valley by the ice and at one place form a long reef across the valley, evidently an old terminal moraine. High gravel banks are present on both sides of the stream and carry some colors, but have never been prospected. A cross section of the surface deposits in the stream channel shows coarse, angular wash above and stratified clays, sands, and gravels below. The sands carry only a few colors, and the best pay comes from the gravelly clays.

Two grades of gold are found; one is coarse and silvery in appearance, the other finer and yellow. Native copper and native silver are both present. Crow Creek gold assays a little less than $15 per ounce, thus being lower in grade than that from any of the other creeks of the Turnagain Arm district. Hydraulic methods of mining have taken the place of the pick and shovel, and Crow Creek now possesses the largest hydraulic plant in the Cook Inlet country.

COOPER AND STETSON CREEKS.

Cooper Creek heads in the divide separating the drainage into Resurrection Bay from that into Cook Inlet, and joins Kenai River 3 miles below Lake Kenai. It and its tributary, Stetson Creek, are the only streams of the Kenai River drainage which have been productive up to the present time, although considerable work has been done in a number of places. The high gravel benches near the mouth of the stream would make good ground for a hydraulic plant to handle, but the gold is very unevenly distributed, and the amount so far taken out is small—not over a few thousand dollars—and most of it was obtained from the creek bed of a single claim in one season. Very little work was done on either of these creeks during the past summer.

CHARACTER AND ORIGIN OF THE PLACER GOLD.

The gold from the different creeks varies greatly in appearance and value, ranging from less than $15 on Crow Creek to over $17 on Sixmile Creek. This difference in value is due to the varying amounts of silver and copper associated with the gold. In almost all cases it is flattened and heavy, usually smooth, and occasionally striated as if it had been rubbed against a rough surface. Any attempt to explain its distribution must take into account the action of glacial ice in the transportation and rearrangement of the gravels. It is believed that while probably most of the gold is of local origin, a small part, like the gravels associated with it, may possibly have been brought to its present place through the agency of moving ice.

AURIFEROUS LODES.

It has been said that practically all the gold is obtained from placer deposits, but at a number of localities quartz veins are being prospected, and these are of interest in connection with the question of the origin of the gold in the gravels.

Bear Creek.—At the head of Bear Creek a small quartz vein carrying gold values has been partly opened during the last year. The chief part of the season was devoted to the erection of a boiler house and head frame, but samples of ore taken out while enlarging a small shaft show free gold in a quartz gangue containing pyrite, galena, and sphalerite with a little copper stain.

Sawmill and Slate creeks.—On Sawmill Creek 6 miles east of Sunrise, also near by on Slate Creek and the shore of Turnagain Arm, quartz veins carrying pyrite, arsenopyrite, chalcopyrite, galena, zinc blende, and free gold are found in fault planes running about east-northeast. The country rock has been disturbed by faulting since the ore was deposited, thus cutting off the veins and making it difficult to find their continuations. A picked quantity of ore put through a small arrastre on Sawmill Creek yielded a fraction over $26 per ton.

COPPER.

Native copper associated with gold in the gravels was found in small quantity by prospectors on Lynx Creek. Its presence led to the discovery of the outcrop of a vein, carrying copper sulphides, on the mountain side at the head of the stream. During the summer a company was formed, and the work of developing the property was begun. An adit level was driven with the expectation of striking an ore body at some depth below the outcrop, but at the time our party left the peninsula this had not yet been reached. If this prospect should develop into a paying mine, connection with the line of the Alaska Central Railroad could be established without great difficulty.

GOLD DEPOSITS OF THE SHUMAGIN ISLANDS.

By George C. Martin.

APOLLO CONSOLIDATED MINE.

Location and output.—The Apollo Consolidated mine is situated near the southern end of Unga Island, about 3 miles west of the town of Unga and 1 mile west of the head of Delarof Harbor. The post-office is Apollo. The mine has been producing since 1891, and has yielded a total of between $2,000,000 and $3,000,000.

Previous work.—The occurrence was described by Becker[a] in 1898. The writer visited the mine in 1904, and gathered a few additional facts concerning the occurrence and the geology of the region.

Character.—The deposit is described by Becker as a reticulated vein or zone of fracture in a large mass of andesite and dacite. The ores consist of free gold, pyrite, galena, zinc blende, copper pyrite, and and native copper. The ore is free-milling, a large part of the gold occurring in the native state. The gangue minerals are quartz and subordinate amounts of calcite and orthoclase. The ore body strikes N. 43° E. and is, in general, vertical. It is from 5 to 40 feet wide and forms a shoot that pitches northward. The southern end of the shoot comes to the surface at an elevation of 600 feet at the present southern limit of the workings, and narrows and becomes of low grade at the northern end at a depth of about 800 feet. An attempt is now being made to reach the ore body at lower levels by a shaft and tunnel.

The best ore bodies are said by the management to occur wherever two diagonal sets of fractures intersect. The profitable ore is said to carry from $1 to $50, averaging perhaps $8.

The country rock has been mineralized to a certain extent on either side of the main ore body, and smaller and less rich ore bodies parallel to the main one are known.

Age.—Regarding the age of the deposit, Doctor Becker concludes that the country rock is Miocene or post-Miocene, from its lithologic similarity to andesites, which are supposed to overlie the Miocene at the north end of the island. He would accordingly make the mineral veins of very late Tertiary of post-Tertiary age.

The writer has observed that some at least of the andesites at the north end of the island are apparently below the Tertiary sediments either by unconformity or by intrusion. He furthermore believes that lithologic similarity of the andesites is an insufficient basis for an

[a] Becker, G. F., Reconnaissance of the gold fields of southern Alaska: Eighteenth Ann. Rept. U.S. Geol. Survey, pt. 3, pp. 12, 83-85.

age correlation across 11 miles of rugged country which is geologically unknown. Such correlation is especially hazardous in view of the fact that on the adjacent mainland of the Alaska Peninsula there are large areas of both Mesozoic and Tertiary andesites which resemble the andesites of both these Unga localities as much as the latter resemble each other. He therefore would conclude that the Apollo deposits may be either of late Mesozoic or of Tertiary age.

NEIGHBORING DEPOSITS.

The King mine, about half a mile north of the Apollo mine, has produced a small amount of gold. The occurrence is said to be similar to that of the Apollo and is believed to be on the same lead, for it is in the line of strike of the latter.

The Shumagin group of claims, on Baralof or Squaw Harbor, about 2 miles north of the Apollo mine, is said to be a similar occurrence. The development here has been principally assessment work.

Becker reports intensely decomposed andesites, heavily charged with pyrite, at Red Cove on Popof Island, about 9 miles northeast of Apollo.

The larger part of Unga Island is made up of similar andesites and dacites, and evidences of mineralization have been seen by the writer at various and widely scattered places. So far as they have been examined by the writer none of these rocks contain workable amounts of gold.

SAND POINT BEACH PLACERS.

The beach sands near Sand Point, on Popof Island, were washed for gold during the summer of 1904. The exact locality is about 1½ miles south of Sand Point post-office and just south of the low sand spit projecting into Popof Strait. The productive beach is about three-fourths of a mile long. The amount of gold taken out during the months of July and August is estimated at about $5,000. From 20 to 40 men have been at work with rockers washing the coarse sand and gravel. All of the gold is found below mid tide and most of it around big stones at the level of low tide. It is said that most of the men make about $4 a day, but a few have done much better than this. The local price for gold in September, 1904, was $13.75 per ounce, which is said to be considerably below the actual value. The gold hitherto obtained is fairly coarse, the finer dust probably having been lost through the inexperience of the men, who are largely fishermen.

The gold is undoubtedly derived from neighboring mineralized zones in the andesites, which make up the greater part of this and Unga Island. The deposits known at present to be gold bearing are restricted to the low-tide level of about three-fourths of a mile of beach. Other similar deposits will doubtless be found on the adjacent shores.

AURIFEROUS QUARTZ VEINS ON UNALASKA ISLAND.

By Arthur J. Collier.

INTRODUCTION.

Unalaska Island, of the Aleutian chain, lies west of and near one of the most frequented routes from the Pacific Ocean to Bering Sea and is important chiefly for its splendid natural harbor, on which are located the two coaling and trading stations, Dutch Harbor and Unalaska. Several years ago an unsuccessful attempt was made to develop and mine some gold-bearing quartz veins near the village of Unalaska. A three-stamp mill and a cable tramway to connect the mill with the mine were erected, but these are now in a state of ruin. This locality is so accessible and so conveniently situated with regard to the harbor that a very low-grade ore could have been handled at a profit. Although this deposit is not thought to be of economic value, the following description of the old workings, which is based on a hasty examination made by the writer last summer, is given, in order that this mine may be compared with the gold mines of Unga Island, described by Martin, and also to indicate the possibility that valuable gold-bearing deposits may occur in the Aleutian Islands. Quartz veins of economic value are reported by prospectors on several of the islands farther west.

TOPOGRAPHY.

The topography of Unalaska Island is rough and irregular. Mount Makushin, its highest mountain, is over 6,000 feet high. Except for a few small gravel plains which fringe some of the bays the hills and mountains rise directly from the water and there is practically no level ground.

GEOLOGY.

The hard rocks of the islands are volcanic and consist of interbedded tuffs and flows that are cut by numerous dikes. The most common rocks are dark-gray andesites.[a] That some of these rocks were erupted in the Tertiary period is proved by fossil plant remains contained in the tuffs.[b] Volcanic activity has persisted to the present time in Mount Makushin, which still has occasional eruptions.

[a] Emerson, B. K., Harriman Alaska Expedition, vol., 6, Geology, 1904, p. 29.

[b] Dall and Harris, Correlation Papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 242-243.

QUARTZ VEINS.

South of Dutch Harbor for several miles the rocks are cut by a system of nearly vertical joint planes which extend approximately east and west. Mineralization has occurred along these joints, and in some instances quartz veins have been formed. Several such quartz veins are exposed in the bluff west of Unalaska, where they have been prospected by short tunnels. The best example, however, is found at the gold mine located 1½ miles south of Unalaska and about a quarter of a mile from the shore of Captains Bay, where a number of small veins of this kind are contained in compact gray andesite. The largest of these forms the main ore body of the mine and has been opened for about 200 feet. It has a maximum width of 6 or 7 feet, but thins out in both directions from the widest part and at the ends of the tunnels is not over 1 or 2 feet wide. The samples obtained here consist of kaolin and cellular quartz, heavily stained with iron in the form of limonite. Samples obtained on the dump and around the mill indicate that a considerable portion of the ore originally contained unweathered pyrite and other sulphide minerals. A sample taken by the writer from the face of the drift at the principal ore body was assayed by E. E. Burlingame & Co., of Denver, who report .02 ounce of gold to the ton and a trace of silver. It is reported that before the mill was built assays promised very high values, which were not realized from the ore when milled.

DEVELOPMENT.

The main tunnel runs east from the entrance about 20 feet, then turns south, crosscutting the joint system. The principal ore body of the mine, which is developed by short drifts, is crosscut about 50 feet from this turn, but the tunnel is continued southward about 100 feet farther to a well-defined but apparently little mineralized joint running east and west, which it follows east for several hundred feet. At the end of this distance there is a crosscut to the north which probably falls a little short of reaching the line of the extension of the main ore body. A few prospectors were on the ground in 1904, preparing to resume work in the mine with a view to determining the extension of the main ore body.

RAMPART PLACER REGION.

By L. M. Prindle and F. L. Hess.

GENERAL STATEMENT.

Previous work.—The Rampart, Birch Creek, Fortymile, and Fairbanks regions are the four important centers of gold production in that portion of the interior of Alaska which is included between the Yukon and Tanana rivers. All of these regions have been visited at different times by parties from the United States Geological Survey, and the results of the work in the Rampart region are presented in reports which have been published, or are in course of publication by the Survey[a]. It was in the course of a geologic reconnaissance trip overland from Eagle, by way of Fairbanks to Rampart, during the field season of 1904, that the facts which form the basis of this short description were ascertained.

Location.—The Rampart region is in the far western portion of the Yukon-Tanana country, where the distance between the two rivers in a north-south direction is only about 50 miles. It is 140 miles west of the Birch Creek region and 80 miles northwest of the Fairbanks region. The creeks, which have thus far proved to be of economic importance, are all within about 30 miles of the Yukon, and belong to the drainage systems of both the Yukon and Tanana rivers. Rampart, the supply point, is situated on the Yukon River, about 70 miles above the mouth of the Tanana.

Communication and transportation facilities.—A government telegraph station affords rapid communication with other portions of Alaska and the outside world, and supplies are received either by way of St. Michael or Dawson. Those shipped by way of Dawson reach the region earlier in the spring, as the upper river is first open to navigation. The first-class passenger rate during the past season from

[a] Spurr, J. E. Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 87-392.

Collier, A. J. The Glenn Creek gold mining district, Alaska: Bull. U. S. Geol. Survey No. 213, 1903, 49-56.

Brooks, A. H., A reconnaissance in the Mount McKinley region, Alaska. In preparation.

Seattle to Rampart by way of St. Michael was $127.50; that by way of Dawson, $111. The freight rates vary greatly, according to the kind

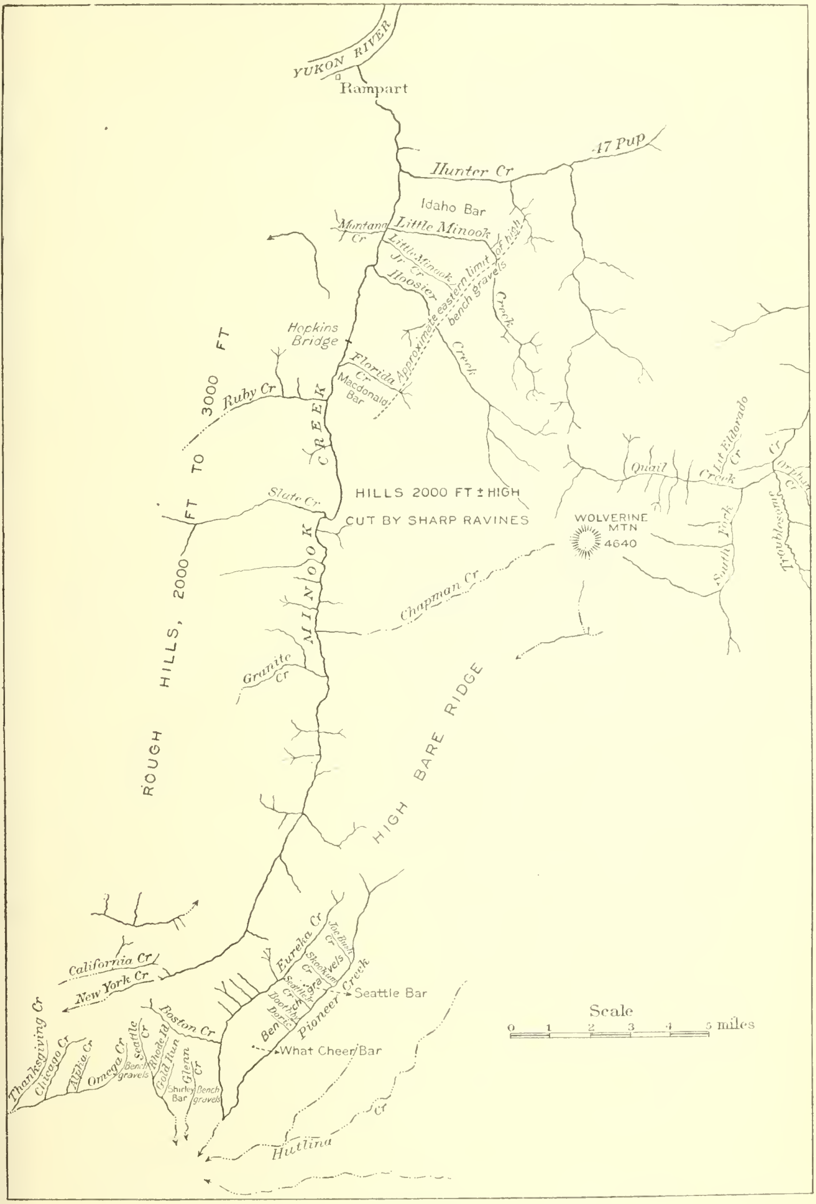

FIG. 6.—Sketch map of the Rampart placer region.

of material and time of the year. The approximate rates on ordinary supplies by way of St. Michael and Dawson, respectively, were $57 and $106 a ton.

In the winter transportation to the creeks is either by dog or horse sleds, the rates varying from 2 to 6 cents a pound according to the distance. In the summer pack horses are used, and the rates vary from 4 to 15 cents a pound. The summer trails are generally bad and remain in about the same condition from year to year.

Mining activity.—The region has produced gold continuously since 1896. New discoveries have been made from time to time, and the discovery of good pay in a new locality during the past year shows the possibilities even in a district that was believed to be thoroughly prospected. During the past season prospecting was being actively carried on throughout the region, and men were found investigating creeks, where in 1902 nothing was being done. Hydraulic methods have been introduced, and the last steamers up the river brought many tons of hydraulic pipe and other supplies for several plants which are in process of installation. The production of the region during the last year has been about $235,000, and the total production up to the present time is probably over $1,000,000.

GEOGRAPHIC SKETCH.

RELIEF.

The Rampart region is one of rather strong relief, ranging from 4,640 feet above sea level at the summit of Wolverine Mountain to somewhat over 400 feet on the Yukon at Rampart. On the northern and southern sides of the Yukon-Tanana country there is generally observable a difference in topographic expression, which in the narrower space between the two rivers is brought into sharper contrast. The divide between the Yukon and the Tanana rivers is about 25 miles south of the Yukon. The area north of the divide is rough, and the high peaks of Lynx and Wolverine mountains are the most prominent features. Steep-sided ridges separate the many deep, narrow canyons whose similarity has frequently led to confusion and justifies the name "Troublesome Country," applied to a portion of the region. South of the divide long, gradually sloping ridges separate the more open valleys and merge finally into the extensive flat of Baker Creek, a tributary of the Tanana.

An area about 24 miles long, with an extreme width of 15 miles, includes all the localities where work is now in progress. The southern portion of this area is cut diagonally by the divide which, with a minimum altitude of about 2,000 feet, extends in a northeast-southwest direction and separates the headwaters of the two drainage systems.

DRAINAGE.

The drainage of the region is shown in the accompanying sketch map, which has been prepared by Mr. Hess from data collected at

different times by the several parties from the Geological Survey, and while based largely on foot traverses represents the drainage systems with comparative accuracy.

YUKON DRAINAGE.

The most important streams north of the divide are Minook and Troublesome creeks. Minook Creek is the largest stream in the Rampart region. It is about 25 miles long and flows through a narrow valley in a nearly straight course, almost directly northward, to the Yukon River. The grade in the lower portion of the valley is probably less than 50 feet to the mile. The stream is generally confined in one channel, but in portions of the valley is distributed over a flat several hundred feet wide. At times of low water the stream is shallow, easily fordable on foot, and the bars are traveled by pack trains; at high water it is impassable.

The western side of the valley is a steep slope which rises to the height of 1,000 feet or more above the stream. In the upper portion of the valley steep ridges crowd in closely on either side. On the east these crowded ridges gradually give place northward to a country of different character, which is related to the stream development of the region and has an economic interest. Minook Creek, for a portion of its length, flows inconspicuously in a narrow canyon 20 feet below the level of a bench that slopes gradually upward to the base of the ridges on either side. This bench attains a maximum width of only a few hundred feet, and though it is apparently the bottom of the valley it is in reality an old floor in which the present shallow canyon has been cut. This old floor, which is so closely related to the development of the stream 20 feet below it, is of importance in that it exemplifies on a small scale the results of a process which, operating for a long time under different conditions than the present, has produced the bench that is so prominent east of the valley. The "high bench" as it is locally called, with its steep streamward-facing slope, bounds the lower half of the valley, and its surface, 500 feet or more above the stream, rises gradually toward the base of the hills to the east and widens northward to a maximum width of about 3 miles.

This bench with its gold-bearing gravels has long attracted the attention of miners, and while this is not the place for a detailed history of stream development it is interesting to note the fact that the high bench stands probably in the same relation to Minook Creek as the small local bench above described does to the stream which has cut below it. It is only a more prominent result of processes which are still at work, which have left other less prominent benches at lower levels, and which have brought about these results at different

times through differences in elevation with reference to the water level. The eastern extension of the high bench gravels, so far as traced, is indicated on the accompanying map (fig. 6, p. 105).

The important tributaries of Minook Creek from the east are Hunter, Little Minook, Little Minook, Jr., Hoosier, Florida, and Chapman creeks. The largest of these is about 15 miles long. Their ramifying headwaters have deeply incised themselves within the steep-sided high ridge which limits in this direction the drainage area of Minook Creek, and they all enter the main valley by narrow V-shaped valleys which cut the high bench above described into several portions, to some of which distinctive names have been given by the miners. The important tributaries from the west are Ruby, Slate, and Granite creeks. These head several miles back from the main valley and are similar in character to those that flow from the other side.

Troublesome Creek is about 12 miles east of Minook Creek. It receives several tributaries which drain the area between Lynx and Wolverine mountains and flows in a general northerly course to Mike Hess Creek. Its course for the most part is outside of the area here considered. The valleys of the upper tributaries, like those of Minook Creek, are narrow, but their heads are frequently open, park-like spaces bounded by precipitous rocky slopes. Terraces are common but are not developed to so great a degree as in the valley of Minook Creek. Quail Creek, the most important tributary, heads opposite Hoosier Creek, and its smaller branches drain the steep flanks of Wolverine Mountain.

TANANA DRAINAGE.

The area south of the divide is of a different character. The two elements that stand out most prominently in the landscape are the ridges and valleys of the southern slope of the divide and the extensive lowland known as Baker Flats, across which flows Baker Creek. A low ridge bounds the valley of Baker Creek on the south, and above this ridge, in clear weather, are visible the lofty masses of Mounts McKinley and Foraker, 160 miles away.

The streams of economic importance are only a few miles long. They flow from their sources on the divide in more or less parallel courses southward and westward. After leaving the base of the hills they unite with one another, lose themselves in Baker Flats, or find their way by winding courses to Baker Creek. The heads of the valleys are narrow and deep like those of the northern slope, but after leaving the region of the high divide the valleys become more open, the ridges between them lose their roughness, maintain an even, bench-like character for a considerable distance, and then descend very gradually to the level of Baker Flats.

A most important feature of these valleys—one that forces itself again and again on the attention of the observer—is their unsymmetrical character. The southeast side is, in most cases, an abrupt descent of several hundred feet, unbroken by tributaries. The northwest slope extends very gradually upward, in some cases for a mile or more back from the stream, and then breaks off abruptly to form the steep side of the neighboring valley. Its surface is worn by tributaries which have formed short valleys of their own, and these, in their backward extension, have in some cases broken the continuity of the main ridges. Benching has been an accompaniment of stream development, as on the northern side of the divide, and these gradual slopes have presented favorable conditions for the retention of the gold-bearing gravels which have been deposited upon them.

VEGETATION.

The valleys and slopes of the larger streams and some of the benches are timbered with a light growth of small spruce and birch. There is some tamarack in the valleys. Grass grows luxuriantly on portions of the high bench of the Minook Valley, and is abundant in the small draws throughout most of the region.

The Government has an agricultural experiment station across the river from Rampart, and at Hot Springs, a locality near the Tanana River, where conditions are especially favorable for gardening, private parties have been for some time raising vegetables in large quantities and selling them to the miners.

GEOLOGIC SKETCH.

The geology of the region is complex. The rocks include several formations which have been closely folded, metamorphosed, and intruded by a variety of igneous rocks. They range in age from Devonian or older to the Quaternary.

STRATIFIED ROCKS.

The oldest rocks in the region are apparently the garnetiferous mica-quartz-schists and marbles. These are found on Ruby Creek and the ridge north of Ruby Creek, which forms the western boundary of the valley of Minook Creek. They occur also on Minook Creek below the Hopkins bridge. These schists were not observed in any other portion of the region. They resemble those of the Fortymile and Birch Creek regions.

In the Yukon-Tanana country there are large areas of shales, cherts, conglomerates, limestones, tuffs, and diabases, which occur in rather constant association at widely separated localities. These have been grouped by Spurr into one formation and called the Rampart series.[a]

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[a] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 155–169.

Their age has been determined as Devonian. In the Rampart region and farther east and south there are black and gray shales, cherts, thin beds of conglomerate composed largely of chert pebbles and gray and black schistose, more or less graphitic grits and massive limestones. A large mass of tuffs and diabasic rocks are associated with these rocks in the northern portion of the region. Some of the limestones have yielded Devonian corals. In the absence of criteria for their separation, all of these rocks are provisionally considered as belonging to the Rampart formation. They form the bed rock throughout most of the drainage areas which have been described.

The flanks of Lynx and Wolverine mountains are formed of black grits and shales. Fragments of dicotyledonous leaves were found in the grits, and the shales also occasionally contain obscure plant remains. The shales are frequently indurated, spotted, and contain metamorphic minerals, due probably to the intrusive granite which forms the summits of these mountains. Similar shales are associated with vitreous quartzites along the ridge that bounds the drainage area of Minook Creek on the east. Their separation from shales which belong apparently to the older formation is not easy, and all that can be definitely affirmed at present is that there is a formation of grits and shales which occupies generally the highest portions of the region and which is at least as young as the lower Cretaceous, and probably much younger.

The general strike of the formations is northeast and east, and the folding has been intense. Evidence of the force which has been at work is afforded by quartzite and limestone breccias.

Sandstones and conglomerates, with associated coal, occur in the lower valley of Minook Creek and along the Yukon, and these have been considered as members of the Kenai formation. The gravels of the high bench are probably of Pleistocene age.

IGNEOUS ROCKS.

Igneous rocks are present in abundance. Granitic and monzonitic intrusives form a large portion of the two highest peaks, and the rocks throughout the region are cut by numerous small dikes of granite, diabase, and intermediate types. The most extensive mass of igneous material is found in the northern portion of the region, where the lower valleys of Little Minook and Hunter creeks and the ridge to the south of Rampart are composed mostly of diabasic rocks and associated tuffs. Basalt and associated volcanics occur on Minook Creek below the mouth of Hunter Creek and also opposite the mouth of Little Minook Creek.

ECONOMIC DEVELOPMENT.

There are two main areas of present gold production. The one iere called the Northern area includes tributaries of Minook and 'roublesome creeks; the other or Southern area, called generally he Glenn Creek mining district, comprises the small streams of the outhern slope, tributary to Baker Creek.

NORTHERN AREA.

The eastern tributaries of Minook Creek which have produced gold re Hunter, Little Minook, Little Minook, Jr., Hoosier, and Florida. glance at the sketch map shows the relations of these to one another nd to the country which they drain. It will be noticed that the ongest of them have their sources several miles east of the high ench, while the courses of the smaller tributaries—Little Minook, r., and Florida—lie almost wholly within it. The varieties of bed ock found in the valleys of these streams are quartzites, black and ray slaty shales, limestones, cherts, and diabase with associated tuffs.

Little Minook Creek.—Little Minook is a small creek about 8 miles ong and flows in a narrow V-shaped canyon, which is about 500 feet elow the general level in the lower portion of the valley, where the tream has a grade of 100 feet or less to the mile. Mining is confined) the lower 3 miles of its course. The distance from the mouth to ie town of Rampart is about 4½ miles, and the winter and summer reight rates 2 and 4 cents a pound, respectively. The creek early ttracted the attention of miners, and since 1896 has produced approximately $475,000.

The depth to bed rock varies from a few feet to about 25 feet, and ie deposit consists of muck and gravel. The muck is of variable iickness, reaching a maximum of 16 feet, and is in some places absent. he maximum thickness of the gravels is about 12 feet. They include great variety of rocks, among which diabase and tuff are perhaps the ost abundant. Quartzite bowlders are common, and there is a considerable proportion of vein quartz. The gravels have been supplied om at least two sources. Angular or subangular material has been erived from the bed rock of the sides and bottom of the valley and ell-rounded material from the high bench in which this portion of ie valley has been cut. Bowlders 2 to 3 feet in diameter are common. he pay gravels are from 1 to 3 feet thick and from 50 to 200 feet ide. The gold is well worn, often coarse, generally finer in the wer portion of the valley, and is of high grade, $18 an ounce being ven for it in trade. Values are found ranging from $2 to $10 per juare yard of bed rock. It is interesting to note that gold has never een found in any quantity on Little Minook Creek above the point here it receives the drainage from the high bench gravels.

Ground was being worked on a few of the claims during the past summer by both the open-cut method and steam points. Much work has been done in the past; some of the ground has been "gophered" considerably, and although there is still good ground, the condition in which it has been left has often increased the expense of working it.

Hunter Creek.—Hunter Creek is similar in character to Little Minook Creek. The maximum depth to bed rock, so far as observed, is about 40 feet. The thickness of the gravel is about the same—12 feet—as on Little Minook, and the proportion of bowlders is greater. The gold is finer, and some of it is rough. Barite is often associated with the gold. As far as could be learned, gold is not found in paying quantities above the eastern limit of the high bench gravels. Decomposed tuffs and loosely consolidated shales and sandstones containing plant remains form the bed rock in the lower portion of the valley, and this soft bed rock may easily be mistaken by the miner for stream deposits associated with gravels. The stream gravels lie above these, not below them, and the mere fact that they are soft does not prove that they belong to the stream deposits, as do the muck and sandy layers that are frequently found above the gravels. The miner may often save much time and labor by studying carefully the character of the bed rock, wherever it is exposed on the sides or bottom of the valley, and comparing it with the material found by him in the ground which is being worked.

Considerable work was being done on Hunter Creek. One of the most interesting developments has been the introduction of a hydraulic plant. A ditch about a mile long carries 300 miner's inches of water to the ground and gives a head of 75 feet. The ground is worked by what might be termed fractional ground sluicing. The thawed surface layer is ground-sluiced to the frozen surface, and this left a week or more to thaw, when another layer, from 1 to 2 feet in thickness, may be ground-sluiced away. This method is said to effect results quickly and very satisfactorily. On another portion of the creek a flume 2,000 feet long has been constructed, and this brings water to a low bench only about 16 feet above the creek. The gravel is ground-sluiced away and about 1½ feet of bed rock shoveled in.

Little Minook, Jr., Creek.—Little Minook, Jr., is a small creek, only about 2 miles long. The narrow valley of the lower portion opens out above to a broadly V-shaped depression in the high bench. There is about 12 feet of muck on the 4 to 5 feet of gravel. Pay is said to have been found over a width of 60 feet. Much of the ground has been worked out.

Hoosier Creek.—Hoosier Creek heads far back toward Wolverine Mountain and flows northwestward through a deep, narrow canyon. Its general characters are the same as those of Little Minook Creek. The grade is about 80 feet to the mile in the lower portion of the

valley. The gravels vary from 4 to 20 feet in thickness, and the gold is mostly on the bed rock. The upper portion of this valley, like those of the other creeks, has never been productive. Preparations have been made to work the gravels by hydraulic methods at a point about 2 miles above the mouth. Ditches and flumes having a combined length of 4,300 feet and a capacity of 500 inches give a head of nearly 80 feet. An elevator had been placed in position and the plant was about ready for active work.

Florida Creek.—Florida Creek has produced some gold, but at present little work is being done.

Interstream or "bar" gravels.—The areas lying between the streams which have been described, for a distance of 2 to 3 miles east of Minook Creek and at an altitude of 500 to 700 feet above the creeks, have a strikingly bench-like surface and are mantled with a deposit of gravels, which is said to be in places at least 100 feet thick. These areas are locally termed "bars," and distinctive names have been given to them, such as "Idaho bar" and "McDonald bar." The canyons of the streams are sharply cut below them, and they appear as portions of a once continuous surface that was related apparently to the drainage system of Minook Creek. The gravels include quartzite, quartzite breccia, some vein quartz, a small proportion of chert, and much fine material, consisting of decomposed fragments of softer rocks. The gravels are coarse, and bowlders 2 to 3 or more feet in diameter are common. Gold has been found in them at widely separated localities, and much work has been done in investigating them, especially on "Idaho bar," directly north of Little Minook Creek.

The facts that they are gold bearing; that the main streams cease to be productive above the zone of these gravels; that the minor tributaries, like Little Minook, Jr., which drains only gravel-covered areas, contain gold; and that most of the creek gold, wherever found, is much worn, all seem to point to them as the source of perhaps the greater portion of the gold found in the stream gravels, without, however, excluding the possibility of its derivation in part from the bed rock through which the canyons have been cut. There is no reason to believe that gold is evenly distributed in small quantities throughout the bench gravels, or that it is anywhere concentrated in them to such a degree as in the gravels of the present valleys. These valleys have a trough-like character, where conditions have been favorable for concentration within narrow limits. The gravels of the benches have been reworked by the present streams, and conditions have been favorable to a high concentration of the gold contained in them. This locality probably illustrates the process of reconcentration, the importance of which is strongly emphasized by Brooks in the Nome report.[a]

[a] Brooks, A. H., Reconnaissance in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 149.

There has been much speculation by the miners as to the source of the bench gravels. The position of the benches seems to show relationship with Minook Creek. The material of the gravels is such as is found in place in the upper valley. Bowlders of quartzite breccia are common in the gravels, and a towering mass of this rusty rock occurs near the trail on Minook about $1\frac{1}{2}$ miles above the mouth of Slate Creek. The bench gravels have been found on the south side of Florida Creek, but have not been traced beyond that point. Although fragments of the bench can be traced still farther toward the head of the creek, the opportunity for the preservation of high gravels in this portion of the valley has been limited.

Ruby Creek.—Ruby and Slate creeks enter Minook Creek through narrow valleys from the west. Ruby Creek drains an area composed partly of garnetiferous quartz-mica-schists. The gravels are about 10 feet thick and there is little muck. No pay has been found farther than $1\frac{1}{2}$ miles above the mouth. Silver nuggets are occasionally found and garnet is an abundant associate of the gold. It is not known whether the occurrence here is related to older gravels. Preparations were being made to work the ground by hydraulicking. A head of 154 feet was said to be obtainable and an elevator was to be used in connection with a "giant."

Slate Creek.—Slate Creek, which drains an area lying 2 miles farther south, is about 4 miles long and flows in a narrow valley. There is said to be always at least a sluice head of water, and the grade in the lower portion is about 150 feet to the mile. The bed rock, near the mouth, includes dark shaly limestone, green and purple shales, and cherty beds. All these have been much folded and strike northwest. The main rock of the valley is a dark graphitic schist, which breaks up into pencil-like fragments and contains many quartz seams. Ground has been worked to a depth of 26 feet. Over a width of 50 feet in this valley gold has been found in as much as 3 feet of gravel and to a depth of $1\frac{1}{2}$ feet in bed rock. An $8 piece is the coarsest found up to the present time. Silver is a common associate and an 8-ounce nugget has been found. Copper is said to occur. The absence of garnets indicates that the schists on Ruby Creek do not extend into this valley. The gold has probably been derived from quartz stringers in the bed rock.

Minook Creek.—Gold has been found on several claims along Minook Creek itself, but conditions are unfavorable for working the ground in a small way, and thus far no extensive systematic work has been undertaken. It is proposed, however, to work some of these gravels on a large scale by hydraulicking during the season of 1905.

Quail Creek, of Troublesome.—Prospecting was in progress on Quail Creek, a tributary of Troublesome Creek from the west, and at other localities within this area. The distance of these localities from Ram-

part is 18 to 20 miles. Some sluicing has been done and a small amount of pay has been taken out. The bed rock is mostly black and gray slaty shales, with many quartz seams. Small dikes of porphyry are abundant and some of them show considerable mineralization. The gravels include shale, quartzite, vein quartz, coarse conglomerate, and a large proportion of igneous material. There are gravel-covered benches about 400 feet above the level of Quail Creek and these are being prospected at the present time.

SOUTHERN AREA.

The creeks of the southern slope that are of present economic importance are Pioneer, Eureka, Glenn, Rhode Island, Gold Run, Omega, and Thanksgiving. The Hutlina[a] attracted considerable attention in 1902 but no work was being done there during the summer of 1904. This area was visited in 1902 by A. J. Collier of the U. S. Geological Survey and described by him in the economic bulletin for 1903, to which reference has already been made.[b] The conditions in 1904 were somewhat different and only the most important present developments are included in the following description:

The area is about 30 miles south of Rampart and is reached by the pack trail from Rampart, which follows Minook Creek and crosses the divide at an altitude of about 2,000 feet. The winter and summer freight rates are at present 6 and 15 cents a pound, respectively.

The bed rock is mostly a shaly, somewhat schistose and generally graphitic grit, which contains numerous quartz seams. Quartzites, black slates, cherts, limestones, and granitic intrusives are found in the ridges at the heads of some of the creeks.

Pioneer Creek.—The valley of Pioneer Creek is the most easterly locality which is being worked. The creek is formed by the union of two forks in the high divide, flows southwestward to Baker Flats and crosses them to Baker Creek; its length within the hills is about 6 miles. A steep, level ridge bounds the valley to the southeast and rises almost directly from the creek. The gentle slope of the northwest side is mantled to a distance of half a mile or more back from the creek, and to a height of 250 feet or more above the creek, with bench gravels in which within the past two years good pay has been discovered. A few small tributaries drain the slope and one of them has proved productive. Practically no work has been done on the main creek.

What Cheer bar is located in the lower portion of the valley, about 2,000 feet back from the creek, at an altitude of about 250 feet above it. The ground here has a gradual slope to the creek. The bed rock is schistose grit. This is much jointed and broken

[a] This stream is known throughout the region as the Hootlinana, but the name Hutlina has been adopted by the Board on Geographic Names.

[b] Bull. U. S. Geol. Survey No. 213, pp. 49-56.

and frequently exhibits fine examples of earth creep. The strike is N. 75° E. and the dip in places is high to the northwest. The average depth to bed rock is about 12 feet. The material from the surface downward includes 1 to 1½ feet of muck, 3 feet of rather fine flat wash, 5 feet of yellowish gravel of medium size, and 4 feet of rather heavy wash. The gravels include a large proportion of quartzite, considerable vein quartz, occasional bowlders of coarse conglomerate like that found in the wash of Quail Creek on the northern side of the divide, and some igneous material. Some of the vein quartz bowlders are 2 feet or more in diameter. Most of the gold is found in the lower portion of the gravels. It is well worn and the coarsest piece found was valued at $28. The bench is dry and the summer of 1903 was employed in bringing water to the claim from a point about 4 miles up stream. A ditch was dug around the hillside and flumes were constructed across the small tributaries. The result is a combined ditch and flume 4 miles long, with a capacity of about 3 sluice heads. The ground is worked by open cuts, the dirt all shoveled into the sluice boxes, and the tailings distribute themselves over the slope toward Pioneer Creek. The water was not available till the first of August, 1904, and the men had been shoveling in for about 15 days. Thirteen men were employed and wages were $5 and board.

Seattle bar is located on the same side of Pioneer Creek, about the same distance back from it and 2½ miles farther upstream. The depth to bed rock is about 9 feet, and the gravels are of the same character and arrangement as those of What Cheer bar. The gold occurs next to bed rock and to a depth of a foot or more within it. Some of the gold is flat and some shotty in character. The coarsest found was a piece valued at $9.40. The ground is worked in a small way by an open cut, and good results have been obtained. Water for sluicing is brought by a ditch and hose from Skookum Creek.

The tributaries to Pioneer Creek are all small, have a course down the slope at about right angles to that of the main valley, and cut through the gravel-covered areas of the bench. Their valleys are open and form only shallow depressions. Doric Creek is about three-fourths of a mile upstream from What Cheer bar. It was prospected in the fall of 1902, and during the winter of 1903–4 a small portion of the valley about one-fourth of a mile from Pioneer Creek proved to be very rich. The bed rock is graphitic schistose grit. Besides the local angular material the wash includes a large proportion of gravels from the bench. The ground is worked by drifting in the winter time. The largest bowlders are left at the bottom of the drift. No pay has been found in the upper portion of the valley, and the gold found here is probably derived by reconcentration from the bench gravels. The locality is an instructive one.

The three localities above described are the most important ones in

this valley where pay has yet been discovered, and it is not unreasonable to suppose that with further work other localities may be found on the bench where the conditions were likewise favorable for concentration of the gold.

The bench gravels extend for at least 4 miles along the creek. There is no reason to think they have been brought to their present position from any other direction than that of the present drainage, or by other means than stream action. The most satisfactory explanation of their presence is that Pioneer Creek, under conditions different from the present, left them there. Under this supposition the creek would have occupied for longer or shorter intervals various portions of what is now the bench, and would have had an opportunity to concentrate there in a "pay streak" the gold that was present in the gravels. The occurrence of gold in the gravels of the benches sufficiently concentrated to yield good results points to such an origin.

Eureka Creek.—Eureka Creek is just over the divide about 1½ miles northwest of Pioneer Creek. It parallels the latter and flows in the same direction till, in the lower part of its course, it bends round toward the east and at the edge of Baker Flats is joined by Pioneer Creek. The valley is similar to that of Pioneer Creek; there is the slope on the southeast which descends steeply to the creek and the gradual slope on the northwest. The creek carries normally about a sluice head, or 50 inches of water. In a wet season the quantity may become about 4 sluice heads. The bed rock is grit with graphitic phases similar to that of Pioneer Creek. The bench gravels are not so well developed. The depth to bed rock varies from 6 to 20 feet, and the deposit is muck and gravels. The gravels are from 5 to 16 feet thick and pay occurs up to 6 feet in the gravels and to a depth of 3 feet in the bed rock where this is blocky, and over a width of 6 to 60 feet. The work of saving the gold is increased by the presence of clay. Some of the gold is rough and many pieces are found combined with quartz. Nuggets have been found worth from $25 to $30. The ground is worked by open cut and drifting. The claims are 1,000 feet long and most of the work has been done in the lower portion of the valley.

Glenn Creek.—Glenn Creek is southwest of Eureka Creek and separated from it by a flat-topped gravel-covered spur about the height of What Cheer bar. About 2 miles farther west a similar spur forms the western boundary of the valley of Rhode Island Creek. The space between these spurs is occupied by the drainage areas of a few small streams, the lower valleys of which are comparatively open. The interstream spaces are beautifully benched, partly covered with gravels, and slope gently toward the lowland of Baker Creek. Glenn Creek is the first of these small streams. It is only about 3 miles long and occupies a shallow depression in the gravel-covered

benches of either side. The creek has attracted considerable attention, and the area has been called from it "The Glenn Creek mining district." It has produced altogether about $275,000, and probably over $35,000 during the last summer (1904). The bed rock is a broken schistose slate, and the material on it, composed largely of angular slide rock with about 2 feet of gravel, varies from 3 to 10 feet in thickness. The pay dirt is from 2 to 3 feet in thickness and the gold is found also in crevices in the bed rock. The gold is well worn, often shotty, and some of it is rather fine. Nuggets have been found worth over $90. The occurrence is probably due largely to secondary concentration. The ground is worked at present mostly by open cut. During the past season there were over 20 men working on the creek.

Shirley bench.—Shirley bench, on the west of Glenn Creek and about 150 feet above it, has produced considerable gold. The gravels vary from 2 to 9 feet in thickness. The material is mostly fine, but there are bowlders of quartzite and intrusive rock similar to that outcropping in the ridge at the head of Glenn and Rhode Island creeks. Gold is found all through the gravels and is well rounded and "shotty" in character. The ground is worked by open cut. Owing to the scarcity of water, a centrifugal pump was used to return the water from the tailings to the boxes.

Rhode Island Creek and Gold Run.—The ground on Rhode Island Creek is more favorable for drifting and no summer work was being done.

Gold Run drains a portion of the bench on the western side and flows into Rhode Island Creek. The depth to bed rock is 16 to 18 feet and the material is mostly well-worn quartzite, grit, and slate. Here also the gold is shotty. A considerable amount was taken out during the winter of 1903–4, but the ground is difficult to work on account of water. The occurrence is probably another case of secondary concentration.

Omega Creek.—Omega Creek is about a mile west of Rhode Island Creek and is separated from it by a conspicuously flat-topped ridge, like that between Eureka and Glenn creeks. The creek flows at first southwestward and bends round gradually toward the west. The valley is limited on the southeast by a comparatively steep slope and on the northwest by a slope of a bench-like character, which rises gradually to the base of the ridge at the head of the creek. The bed rock is schistose grit and slate, and the gravel is composed mostly of angular fragments of these rocks with some quartzite and vein quartz. The occurrence of gold is interesting in that along with some smooth gold there is a considerable quantity that is rough. The nuggets found generally contain quartz. The creek became a producer during the summer of 1903, and thus far work has been done on only a few claims.

Thanksgiving Creek.—Thanksgiving Creek is about 1½ miles west of Omega Creek. Gold was discovered here in February, 1903, and con-

siderable work was done during the winter of 1903–4 and the summer of 1904 with good results. The depth to bed rock varies from 6 to 18 feet and there is from 4 to 9 feet of gravel, which is made up of subangular fragments of quartzite, schistose grit, vein quartz, slate, and some intrusives. The presence of much clay causes difficulty in working the gravels. Pay is found in from 1½ to 7 feet of gravel and over a width of 40 to 45 feet. The gold includes both smooth and rough varieties, and some fine nuggets combined with quartz have been found. The creek is worked by drifting and open cuts.

Most of the gold of Omega and Thanksgiving creeks does not seem to have been derived from bench gravels, but rather to be the result of the first concentration of the gold after it has left the bed rock by the action of the present streams. There are many small quartz seams in the schistose carbonaceous grits and some of these are probably the source of the gold.

The gold of the southern area is of much lower value than that of Little Minook Creek and brings only from $15 to $16 an ounce. The total production of the area for the past year has probably been over $150,000.

SUMMARY.

General outlook.—The older creeks, although largely worked out, are still producing some gold, and attention is being directed to known deposits less advantageously located, some of which can probably be made to pay by the use of carefully considered methods, and to new ground, the extent of which has not yet been determined, where good pay has been discovered. The methods employed in the extraction of the gold are open cut combined with ground sluicing and shoveling in, drifting by the use of steam points, and hydraulicking. The cost of production has varied from 25 to 50 per cent of the output, and is probably most often very near the higher percentage named.

Outlook for hydraulic mining.—The installation of a hydraulic plant in any of the placer regions of the Yukon-Tanana country involves the expenditure of an amount of money several times in excess of that required for similar work in the States and should be preceded by much careful preliminary study of all the conditions. The transformation of an available water supply into a powerful tool of excavation and transportation and the use of this tool in the most skillful and efficient manner are among the most important problems of mining. Lack of knowledge and skill may be covered by the results where the ground is very rich, but with ground like that under consideration the possession of these qualities or the lack of them may make all the difference between success and failure. Directors and stockholders of companies planning such work should insist upon and be constantly ready to bear the expense of the intelligent study of conditions and careful management of operations.

RECENT DEVELOPMENT OF ALASKAN TIN DEPOSITS.

By Arthur J. Collier.

INTRODUCTION.

The tin deposits of Alaska which give promise of some economic importance are situated in what is known as the York region, which comprises the western end of Seward Peninsula, though tin in small quantities is much more widely distributed. The tin ore of the York region occurs both in lodes and placers, distributed over an area of about 450 square miles. Stream tin was discovered in the gold placer mines of the Anikovik River, near York, in 1900,[a] since which time prospectors have found the ore at many other localities. These deposits have already been described by the writer[b] in some detail, so that only a brief statement of the geologic conditions is here required.

During the season of 1904 the writer examined many specimens of tin ore and collections of minerals at Nome, made by prospectors who were searching for tin in various parts of Seward Peninsula, and later spent a few days at Cape Mountain and Lost River, the two points where systematic development of tin-bearing lodes was in progress. The tin placers of Buck Creek were not again visited, though considerable mining was in progress there during the season. It is the purpose of this paper merely to describe the developments since 1903.

LODE DEPOSITS.

The prospecting and development of mineral-bearing lodes is necessarily slow and expensive as compared with the rapid development of the placers, and it is scarcely reasonable to suppose that the work which can be done in a short Alaskan season will be sufficient to demonstrate their value. On the other hand lode deposits have the advantage over the placers that they can be worked throughout the whole year in Alaska as well as in any other part of the world. During the season of 1904 development work on tin lodes was in progress at Lost River and Cape Mountain, and new discoveries of tin lodes were reported at Brooks Mountain, Ears Mountain, and in the Darby Mountains, all in Seward Peninsula. These localities will be discussed in the order named.

[a] Brooks, A. H., An occurrence of stream tin in the York region, Alaska: Mineral Resources U. S. for 1900, U. S. Geol. Survey, 1901, p. 270.

[b] Collier, A. J., Tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 229, 1904, and Bull. U. S. Geol. Survey No. 225, 1904, pp. 154-167.

LOST RIVER LODES.

Location.—Lost River, which enters Bering Sea 25 miles east of Cape Prince of Wales, rises near Brooks Mountain about 12 miles from the coast and flows southward. The tin lodes of the Lost River basin are on two tributaries known as Tin Creek and Cassiterite Creek, which flow into Lost River from the east side about 6 and 7 miles, respectively, from the sea. Most of the development work has been done on Cassiterite Creek. The country rock of this whole basin is limestone with some intruded dikes and stocks of granite and granite-porphyry. Tin ore was discovered here in 1903 in connection with a granite-porphyry dike which extends from the hillside above Cassiterite Creek across the mountain to Tin Creek, a distance of 1 mile.

CASSITERITE CREEK DEVELOPMENTS.

A group of claims located along this dike, which was called Cassiterite lode, was bonded in 1903 to capitalists, who in 1904 sent in a well-equipped expedition to examine the claims. Active development was carried on for about a month, when the work was suspended. Other bodies of ore, which were exploited late in the season, have been found by the original locators for several hundred yards northwest of the original discovery. The field relations of the various prospects and croppings of tin ore are shown in the diagram, fig. 7.

The excavations which have been made show that the dike called Cassiterite lode ends about 200 feet east of Cassiterite Creek, and that a similar dike, also tin bearing, outcrops on the west side of the creek about 500 feet northwest of this point. Whether or not this second dike is a faulted portion of Cassiterite lode has not been determined.

The second dike extends westward for a few hundred feet from the point of outcrop noted, then joins a third dike which extends northwestward along the top of the spur between Lost River and Cassiterite Creek. In detail the results of this prospecting are as follows: At the point of original discovery of tin ore on the west end of Cassiterite lode (marked b in fig. 7) a tunnel and a crosscut show an ore body about 60 feet long by 15 feet wide, the lateral walls of which are the well-defined contacts of the original dike matter with the limestone. The dike rock in this shoot has been altered mainly to kaolin, though the original texture is partially preserved. Cassiterite in fine grains is rather uniformly distributed through this mass, but it is reported that the tin content dropped below 1 per cent at the end of the tunnel.

A second tunnel, driven on the dike about 200 feet east and 200 feet higher on the hill, shows the porphyry in a less kaolinized condition. Here it still contains some tin ore, although in smaller amounts. Samples taken from the croppings of the dike several hundred feet farther east were said to contain traces only of tin.

The attempts to trace the dike westward were unsuccessful, though several prospect holes were sunk in the line of its extension west of the 60-foot tunnel noted above, seeming to indicate that the dike ends near this tunnel. The hillside here is so deeply covered with talus that the actual ending of the dike can not be seen on the surface, and the dike rock was not discovered in place in any of the prospect holes west of the main tunnel. The limestone bed rock reached in these prospect holes is shattered, and the writer was informed by the super-

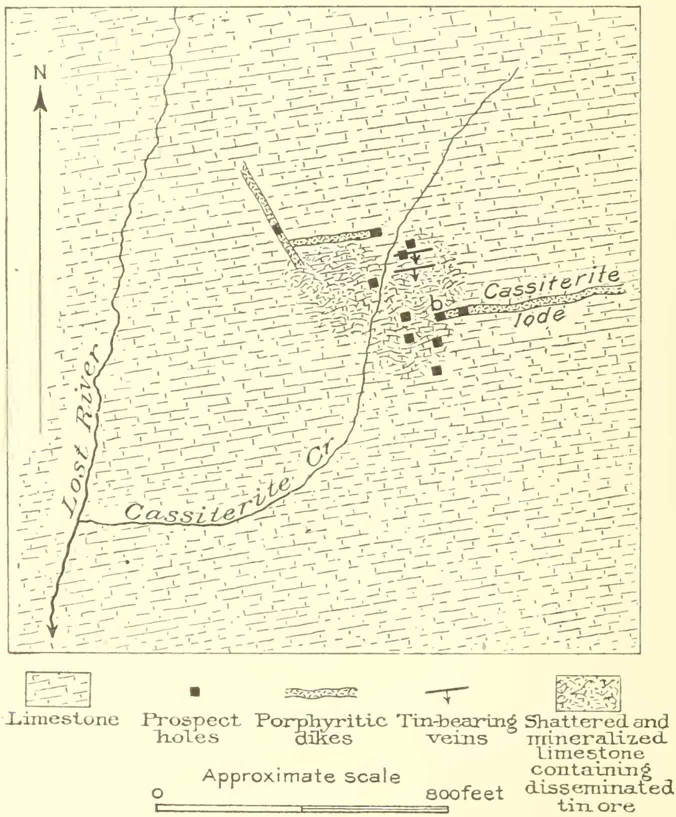


FIG. 7.—Diagram showing field relations of the tin-bearing lodes on Cassiterite Creek.

intendent of the workings that assays made of it usually show traces of tin.

The limestone on the west side of the creek opposite the main tunnel and in line with the extension of Cassiterite lode is very much shattered and filled with many veins, which run in all directions and vary in thickness from a knife edge to half an inch. The limestone along the sides of these veinlets is usually impregnated with cassiterite and other dark minerals in small crystals, so that it is possible that parts of it may constitute a stockwork rich enough in tin to pay for mining.

Two thin veins of tin ore occur in the structural planes of the limestone about 400 feet northwest of the 60-foot tunnel. These strike parallel with the course of the dike and dip toward it at an angle of about 40°. One of these veins, which has been developed for about 100 feet along the croppings, varies from 2 inches to 1 foot in thickness. The ore occurs in large crystals, forming a comb on the walls of the fissure, and it also impregnates them for several inches.

The dike which outcrops about 500 feet northwest of the main tunnel on Cassiterite lode was developed by several shallow prospect holes and crosscuts. The rock resembles that of the Cassiterite lode, and like it carries cassiterite in disseminated grains. It has not yet been developed sufficiently to determine either its extent or the amount of tin ore which it contains. No systematic sampling has been done and no assays have been made.

The general result of the work done on Cassiterite Creek during the the past season is to demonstrate that there is an ore body, about 60 by 15 feet, in the west end of the dike known as Cassiterite lode. This ore body was systematically sampled as far as developed, but the exact average of the assays made has not been reported to the writer, and its extent in depth has not been tested. East of this ore shoot the dike probably does not contain sufficient tin to be of value. The limestones surrounding the west end of the dike contain several small but well-defined veins of very rich ores, and in places are so filled with minute veins as to become practically a stockwork ore body. The bond under which most of the work was done last summer covered only a part of the ground on which tin ore has been found, and work was suspended because the bonding price was evidently too high in the light of these developments. The original locators who remained on the ground worked one of the small veins late in the season and produced and shipped to Seattle 12 tons of ore, estimated to carry from 10 to 20 per cent of metallic tin. Two men working the croppings of this vein and a third hauling with a wagon and team of three horses were able to mine, sack, and haul to the beach one ton of ore a day.

TIN CREEK DEVELOPMENTS.

Tin ore of the same general character as that at Cassiterite Creek has been found on Tin Creek, and prospectors report that the croppings of the lodes have been located, though nothing more than assessment work has been done, and this merely to hold the ground. The locality was not examined by the writer.

The whole region surrounding Lost River has been thoroughly searched for croppings of tin-bearing ledges, with the result that a number of porphyritic dikes, some of which are mineralized with

galena and arsenical pyrites, have been found in the region southwest of Cassiterite Creek. Ore from one of these is reported to yield an assay of 15 ounces of silver per ton.

CAPE MOUNTAIN LODE.

LOCATION AND GEOLOGIC RELATIONS.

Cape Mountain is situated in the extreme western end of the peninsula and takes its name from Cape Prince of Wales. It is essentially a granite boss surrounded by limestones and slates in which it is intruded. Investigations made during the past season show that the contact of limestone and granite is very irregular and that around the margins masses of limestone are often included in the granite, while the granite often penetrates the surrounding limestone in a fringe of porphyritic dikes.

Float ore consisting of cassiterite in association with tourmaline and other minerals has been found at many places on the mountain, and systematic prospecting for tin-bearing ledges has been in progress for the past three seasons, but the development has been slower than at Lost River, mainly on account of a heavy mantle of talus and residuary soil, which makes it difficult to trace the float ore to its bed-rock source. In many prospect holes this covering goes to a depth of 6 or 7 feet. During the summer of 1904 work was done at a number of places, only a few of which were seen by the writer. The most extensive workings were those of the Bartels Company.

THE BARTELS COMPANY'S DEVELOPMENTS.

This company staked many claims around the mountain in 1902 and 1903, and began development work in 1903. The equipment of the company consists of a permanent camp (called Tin City) and central power station, from which wires run to electric drills at the prospecting tunnels. The bed rock in many of the prospect holes carries traces of tin, but ore of appreciable value has been found in place in only one of the tunnels. This tunnel, which is on the mountain one-half mile north of Tin City, is in the granite near its contact with the limestone. The granite in the tunnel is intersected by joint planes that run north and south, or about at right angles to the direction of the tunnel, and the tin ore is not evenly distributed through it, but seems to be arranged in ill-defined streaks that run parallel to the joints. Assays of picked samples from this tunnel have yielded as high as 40 per cent of tin, but no average samples had been taken or assayed at the time of the writer's visit, and the average rock from the dump will probably show only traces of tin. About half a mile north of this tunnel a great deal of float ore of very high grade has been picked up on the surface of the ground, and considerable prospecting by open

cuts has been done to locate the lode. This locality is near the contact between the limestone and a large offshoot from the main granite mass. Probably none of the rich ore has been found in place, though one of the prospect holes shows a thin seam of tourmaline similar to that associated with the tin ore in the contact between the granite and limestone.

The prospecting on this mountain has unfortunately been done mostly on the surface and at many scattered places, usually as assessment work, merely to hold the various claims; consequently the development of possible veins or lodes has not been commensurate with the work done. In only one case has ore containing more than traces of tin actually been found in the bed rock, and further work will be required to demonstrate whether or not ore bodies of commercial value exist.

BROOKS MOUNTAIN PROSPECTS.

Considerable prospecting for tin was done on the surface of Brooks Mountain, which is located about 5 miles north of the Lost River locality, and lode deposits similar to those at Lost River are reported to have been found. The locality has never been examined in detail by the writer, but specimens of ore that were reported to have been found here were seen at Nome. This ore is similar in character to that obtained from the altered porphyritic dikes of Lost River.

EARS MOUNTAIN PROSPECTS.

Ears Mountain is located about 60 miles northeast of Cape Prince of Wales and 50 miles north of Port Clarence. Like Cape Mountain, it consists of a granite mass surrounded by slates and limestones into which it is intruded. Several parties of prospectors searching for tin ores have visited this locality during the last two years, and many specimens of rock supposed to be tin ore have been brought out. With one exception, none of these which were examined by the writer contain more than traces of the metal.

DARBY MOUNTAINS.

Outside of the occurrences noted above, tin ore is not known to have been found in place anywhere in Alaska. These localities are all in the York region of Seward Peninsula. While the writer was at Nome in the early part of the past season, however, a specimen of tin ore said to have been found in the region north of Cape Darby was referred to him by a prospector who had recently returned to Nome from Norton Bay. The specimen seemed to be a piece of granite that had enough cassiterite disseminated through it to make up possibly 10 per cent of its weight. If this find turns out to be genuine, it will indicate a wide distribution of tin-bearing ledges beyond the limits of the York region.

PLACER-TIN DEPOSITS.

GENERAL CHARACTERS OF ALASKAN STREAM TIN.

Tin ore in the form of pebbles disseminated through the alluvium is more easily detected and more easily mined than the same ore confined in the bed rock, and in a region overrun by prospectors searching for placer gold, as is Seward Peninsula, the distribution of the stream tin will be determined long before its sources in the bed rock have been found. Small specimens of stream tin have been found in the northern part of Seward Peninsula, from Cape Prince of Wales to the south shore of Kotzebue Sound, and in the southern part of the peninsula the ore has been found in several streams of the Nome district. The tin-bearing gravels are shallow and of low grade, and in a region of high wages and short working seasons, only the most promising deposits of this kind can possibly be worked at a profit.

YORK REGION.

During the past season placer mining for tin was in progress in the York region on Buck Creek, and good prospects are reported to have been found on York River. Specimens of tin ore were discovered in the gravels of one of the streams of the Fairbanks district in the interior of Alaska. None of these localities have been visited by the writer during the past season.

Buck Creek tin placers.—Buck Creek, which is situated about 20 miles north of York, has been the center for placer-tin mining operations since 1901. During the season of 1904 these operations were resumed on a somewhat larger scale and the ground was handled with horses and scrapers. Iron riffles of the Hungarian type were used in the sluice boxes and about 25 ounces of gold were separated by panning the concentrate from the first three or four bars. An unsuccessful attempt was made to haul tin ore from Buck Creek to York with a traction engine. This machine moved itself several miles up the Anikovik River, on the road from York to Buck Creek, but was unable to cross the tundra. It is reported that about 60 tons of 40 to 50 per cent ore were obtained on Buck Creek and hauled with horses to York. In the latter part of August there was a pile of about 2[illegible] tons of tin ore at York awaiting shipment.

York River.—Considerable prospecting was done early in the season on York River, a western branch of the Pinguk, which flows northward from Brooks Mountain. Stream tin is reported to have been found in the gravels for more than 10 miles along this river. In the samples seen by the writer the cassiterite is in fine grains associated with small amounts of magnetite, garnet, tourmaline, and quartz. The stream is said to be as promising as Buck Creek, but it is somewhat more difficult of access from the coast.

Other localities.—Small specimens of tin ore, consisting usually of only a few pieces, have probably been found during the season on several of the streams where mining was in progress near Nome. One such specimen reported to the writer came from the gold placers on the divide between Dry and Dexter creeks, and a considerable amount of such ore was found on Gold Bottom Creek, at the head of Snake River.

FAIRBANKS DISTRICT.

Cleary Creek occurrence.—Small amounts of stream tin were also found during the season in the placers of Cleary Creek, in the Fairbanks district, on the lower Tanana. A specimen of this kind obtained by Mr. Frank L. Hess, of the United States Geological Survey, consists of several rounded pieces of cassiterite resembling that of the York region. This discovery seems to be of scientific rather than economic importance, since, as in the Dawson region, the mineral is found only in small quantities.

NOTES ON THE PETROLEUM FIELDS OF ALASKA.

By George C. Martin.

INTRODUCTION.

The attempts to develop oil fields in Alaska, which were begun in 1901, were continued during the summer of 1904. The writer has already[a] described to some extent the geology and oil indications in the Controller Bay, Cook Inlet, and Cold Bay fields. These fields, together with much intervening territory, were revisited during the summer of 1904. The following pages contain the additional knowledge gained during the past season and a statement of the progress of development.

CONTROLLER BAY PETROLEUM FIELD.

LOCATION.

The Controller Bay petroleum field is situated on the shores of Controller Bay, about 25 miles southeast of the mouth of Copper River, in latitude 60° 10′ N., longtitude 144° 20′ W. The region within which there are indications of petroleum, and where wells have been drilled, is about 20 miles long from east to west, and 7 miles wide from north to south, and is situated between Bering Lake and Controller Bay and between the ridge west of Katalia and the Mount Nitchawak region.

GEOLOGY.

STRATIGRAPHY.

The rocks of the Controller Bay region include a series of complex semimetamorphosed beds, a series of oil-bearing Eocene shales (Katalla formation), a series of Oligocene coal measures (Kushtaka formation), a series of Miocene conglomerates, sandstones, and shales, a few igneous rocks, and a large area of alluvial and glacial deposits. Of these the petroleum belt proper includes only the Katalla formation, some igneous rocks, and alluvial deposits.

The Katalla formation consists of a series of dark argillaceous and carbonaceous shales, with occasional bands of sandstone, limestone, conglomerate, and volcanic ash. These are the rocks through which the petroleum of the region reaches the surface. They are typically

[a] Bull. U. S. Geol. Survey No. 225, 1904, pp. 365-382.

xposed in the region to the northeast of Katalla along the banks of he Katalla River and in the range of hills to the east of it. From this point they extend eastward, occupying the whole of the peninsula between Bering Lake and Controller Bay and outcropping in all the ills south and east of Bering River except (probably) the Okalee Mountains. Good exposures were seen on the west shore of Bering Lake, and it is possible that some of the shales and sandstones of Kayak and Wingham islands represent the same formation. No stimate could be made of the thickness of the formation because of he complicated structure in all the districts where it is exposed. A ew fossils which have been obtained indicate that the formation is of Eocene age.

The eastern shore of Bering River and Controller Bay, from a point slightly below the mouth of Stillwater Creek to the ocean, is a at plain of sand and mud, constantly growing by the addition of ediment which the streams from the southeastern margin of the Bering Glacier carry and deposit along their courses and at their ouths. Mount Nitchawak, Mount Campbell, Mount Gandil, and ther peaks rise like islands from out this plain of sand and mud. t seems certain that a very short time ago they were islands in an lder extension of Controller Bay which has been filled by the sediment of these glacial streams. These deposits are known to have a hickness of over 580 feet at one point on the Bering River. This aterial floors the valley of Katalla River and of the stream which eads near it and flows into Bering Lake to a depth exceeding 240 eet, and it also fills the lower courses of most of the other streams hich enter Controller Bay.

Another series of deposits contemporaneous with the last, yet different in origin, is made up of the beaches, islands, and bars which e waves of the ocean are building along these shores.

Several igneous masses were seen on the west shore of Bering River, near its mouth. These include several dikes of a light-olored, fine-grained rock (tentatively determined under the microscope to be a microgranite) and a fine-grained, dark-green igneous ock which, upon examination, proves to be a chloritized tuff or olcanic ash.

STRUCTURE.

The structure of this region appears at first sight to be extremely omplex, the strikes and dips being of almost indescribable irregularity. Careful study has, however, shown that part of the irregular utcrops consist of large blocks that have been displaced on the steep illside by gravity, while some of the irregularities may be due to a inor crumpling in the softer beds. Others may be due to faulting, ut the amount of influence of this factor is not known.

After the irregularities due to the above-mentioned causes have been eliminated the following structural features distinctly appear. The region consists of an undetermined number of parallel, closely folded anticlines and synclines, with pitching axes that extend in an average direction N. 35° E. The prevailing strike is northeast and southwest, and the prevailing dip is from 35° to 60°. The most plainly developed of these folds are the Katalla Valley anticline, the Strawberry Point syncline, and the Chilkat Creek anticline.

The Katalla Valley anticline extends through the Katalla Valley in an average direction of N. 38° E. Exposures on the western flank showed strikes of N. 55° E. and N. 85° E. with northwestern dips, varying from 18° to 65° on the west shore of Bering Lake, and a strike of about N. 40° E. with a northwest dip of 70° near the mouth of Deep Creek. The strata are almost continuously exposed along the eastern flank in the high ridge that forms the eastern side of the valley. The strike varies from north to N. 40° E. and the dip is southeast at an angle varying from 32° to 60°. The outcrop in the high southern peak of this ridge is an unexplained irregularity, for the strike is here N. 60° W. and the dip is southward at an angle of 35°. Apparently the strata have been abruptly flexed or faulted at this point, striking almost at right angles to the rest of the ridge.

The Strawberry Point syncline adjoins the last-mentioned fold on the southeast. The rocks are best exposed in the crescent-shaped ridge that forms the northern shore of Strawberry Harbor and presents its concave face toward the sea. The dip is everywhere towarc this concavity, changing from southwest at Point Hey to southeast a Cave Point, showing the presence of a pitching syncline of which only the nose is on land. This fold becomes less evident as one crosses into the steep slopes in the valley of Mary Creek, but can be traced in a general direction of about N. 32° E. almost to Bering Lake. Th outcrops in the valley of Burls Creek are on the eastern flank and nea the northern end of this fold. These outcrops show great local varia tion, many of them doubtless being large blocks which have becom involved in landslides of great magnitude.

The fold next east of this whose presence is definitely established the Chilkat Creek anticline. This is a sharp fold whose axis extenc N. 35° E. through the valley of Chilkat Creek. The center of th anticline is very steep and is locally crumpled. The dip on the flanl averages about 45°.

The ridge east of this valley between it and Bering River is appa ently synclinal, with a strike ranging from N. 35° to 40° E. Th fold is very sharp along the axis, for the rocks at the mouth of Berir River stand vertical, though farther up the river the dip is northwe at an angle of 40°.

The same northeast strike and northwest dip may be seen on Kay

and Wingham islands and in the hills of the Nitchawak region. Each of these areas, considered independently, is therefore monoclinal. The intervening areas, where the solid rock is concealed by water or lowland, are so broad that the general structure can not be made out. The oil region is bounded on the west by an area of semimetamorphosed rocks, from which it is probably separated by a fault.

The area north and northeast of Bering Lake is in greater part of monoclinal structure and of uncertain structural relations to the region south of the lake.

DEVELOPMENT OF THE FIELD.

PREVIOUS DRILLING AND ITS RESULTS.

Fifteen wells had been drilled or were drilling in this region in September, 1904. Of these two are in the Katalla Valley, one is 3 miles east of Katalla near Cave Point, two are on Strawberry Harbor, nine are between the head of Katalla Slough and the mouth of Bering River, and one is on Bering River about 4 miles above its mouth. Of these wells, three (one in the Katalla Valley, one on Strawberry Harbor, and one on Bering River) were abandoned before they reached bed rock. Four of them (one in the Katalla Valley, one at Strawberry Harbor, and two west of the mouth of Bering River) are still drilling. Of the remaining eight wells, three were mentioned in an earlier report.[a] One of these wells is now furnishing oil which is used as fuel at the other wells of the same company. No statistics regarding the present production of the well are at hand, nor is it known how much greater the yield might be if the well were pumped continuously.

The following is a record of this well as reported by the Alaska Steam Coal and Petroleum Syndicate, and published by Mr. F. H. Oliphant:[b]

6 feet surface drift	6
10 feet decomposed shale	16
140 feet light-colored shale	156
18 feet fine-grain sandstone	174
One-half foot coal contained in the sandstone	174½
190 feet dark shale, very hard	364½
One-half foot quartz containing iron pyrites, and contained in the shale	365
1 foot oil sand and flow of oil	1
Total	366
Length of 12-inch casing	220
Length of 9⅝-inch casing	340

Numerous small showings of petroleum and natural gas were encountered as the drill proceeded down, and at 366 feet a large quantity of oil was developed, which flowed some petroleum. The well is said to have continued to flow until capped.

[a] Bull. U. S. Geol. Survey No. 225, pp. 368-369.

[b] The production of petroleum in 1902: Mineral Resources U. S., p. 583.

The amount of authentic information which has been given out for publication regarding the wells is extremely small, but it is reported that none of the remaining five wells have produced oil in commercial quantities. It is furthermore said that none of them have reached depths exceeding 1,100 feet, in which case it may be assumed that the possibilities of the field have not yet been conclusively tested.

Great difficulty has been experienced in all parts of the field in keeping the holes straight and free from water. These difficulties and the distance from all points where special fishing and repairing tools can be procured have made progress very slow and deep drilling sometimes impossible. Perhaps some of the wells would have been more successful if they could have been continued to greater depths.

Mr. F. H. Oliphant, in summarizing the developments during 1903, said of this field:[a]

> The developments in Alaska during 1903 have not resulted in any commercial production of petroleum, notwithstanding the numerous surface indications and the wells that have been completed in the supposed productive territory. The prospectors should not, however, be discouraged, although it may require patience and careful prospecting with the drill to tap the reservoirs, whose existence seems to be indicated by remarkable surface shows of both petroleum and natural gas.

Three wells which were located on mud flats at some distance from high land or from exposure of solid rock had difficulty or did not succeed in reaching bed rock. In two cases the drive pipe was sunk to depths of 240 and 580 feet through mud without reaching solid rock. These experiments show conclusively the inadvisability, in the present stage of development, of attempting to locate wells on the flats. After a field is proved, then the mud flats adjoining it longitudinally may be considered to have a speculative value. At present there is no indication that they are worth anything.

Another illustration of the folly of investing in the low grounds, and also of investing without thorough investigation, is the case of a tract which was staked and sold for $1,700 during last winter. In the spring the supposed land floated and melted entirely away, the stakes having been driven in the ice off the shore of Controller Bay. It is generally believed in the region that there was no intent to defraud.

RELATION OF PETROLEUM TO STRUCTURE.

Most of the more important seepages between Katalla and Bering River fall approximately on three straight lines, each having a general northeast-southwest direction. These lines are nearly parallel to the strike in their vicinity, and are undoubtedly influenced in position and direction by the structure. They probably represent the outcrops of oil-bearing strata. The easternmost of them is on the western flank, but very close to the crest of the Chilkat Creek anti-

[a] The production of petroleum in 1903: Mineral Resources U. S., p. 690.

cline. The westernmost is on the eastern flank, and about halfway down the Katalla Valley anticline. Those in the valley of Burls Creek are in a less certain structural position. The gas springs on the banks of the Katalla River are probably located on or near the crest of the Katalla Valley anticline. It seems probable that in this, as in most other fields, the occurrence of oil is controlled by the structure. The location of the anticlines and the structural position of the strata outcropping at the lines of seepages will probably prove to be the safest guide in the location of the wells.

THE COOK INLET PETROLEUM FIELDS.

But little of economic value can be added to the description of the structure as given in earlier publications.[a] The Mesozoic rocks are much thicker than was previously estimated. The Middle and Upper Jurassic rocks, overlying the surface rock where the wells are being drilled, are about 7,000 feet thick. The underlying beds probably consist of about 1,000 feet of Middle Jurassic, an unknown amount of Lower Jurassic, and probably at least 2,000 feet of Triassic. The structure has already been described.

The first well at Oil Bay was begun in 1898 and has been drilled to a depth of somewhat over 1,000 feet. No log of this well or any very authentic information can be obtained, as the property has changed management several times. It is reported that gas was encountered all the way below 190 feet, and that considerable oil was found at a depth of 700 feet. The flow of oil is reported as having been estimated at 50 barrels. On drilling deeper a strong water pressure was encountered, which shut off the flow of oil. The well is now over 1,000 feet in depth and affords a continuous flow of gas, which at times becomes very strong. Attempts have been made to shut off the flow of water and either recover the lost oil or drill deeper, but without success.

A second well, located about a quarter of a mile west of the older one at Oil Bay, was drilled during the summer of 1904.

Record of well as reported by August Bowser.

	Feet.
Sandstone	200
Shale	120
Oil and some gas	1
Shale (caving)	129

The well was abandoned at a depth of 450 feet because the shale caved so badly.

A third well, located about 250 feet south of the last, was also drilled during the summer of 1904.

The general sequence of strata was the same as in the last well, the

[a] Bull. U. S. Geol. Survey No. 225, 1904, pp. 376-379; Bull. U. S. Geol. Survey No 250, 1905.

shale continuing to the bottom of the hole. The well was cased to a depth of 630 feet. Oil and gas were encountered at a depth of 770 feet, there being three small oil sands, each 6 to 8 inches thick and 4 or 5 feet apart. The production of the well was estimated at 10 barrels. The caving rock was encountered at 830 feet. Work was stopped at a depth of 900 feet at the end of the season. Considerable gas was encountered at various depths, the pressure at times being strong enough to blow the water up in the derrick to a height of 20 feet.[a]

A well at Dry Bay was drilled to a depth of 320 feet in the summer of 1902 without encountering oil. The tools were then lost and the hole was abandoned. In August, 1903, a new well was started in close proximity to the first, but not much was accomplished, and work was discontinued a few months later because of an accident to the machinery. Nothing has been done during last season.

THE COLD BAY PETROLEUM FIELDS.

The hurried observations which the writer made in this field in the summer of 1903, and which have been already published,[b] have been supplemented by a much more careful examination during the summer of 1904. Many new facts have been obtained which make it necessary to redescribe the geology.

GEOLOGY.

STRATIGRAPHY.

The following rocks are exposed in the Cold Bay-Becharof Lake region:

General section in the Cold Bay-Becharof Lake region.

Name of formation.	Age.	Lithologic character.	Thickness in feet.
	Post-Jurassic	Volcanic rock, probably andesite or basalt.	
Naknek formation.	Upper Jurassic	Arkose, conglomerate, sandstone, and shale.	3,000 to 5,000
Enochkin formation.	Middle Jurassic	Shale, sandstone, and a little limestone.	2,000
	Triassic	Shale, limestone, and chert.	
	Pre-Jurassic	Granite, syenite, etc	

The coarse crystalline rocks (granite, syenite, and rocks of similar texture) occur in a belt that runs parallel to the length of the Alaska Peninsula. They cross the lower end of Becharof and Naknek lakes and possibly underlie the Cold Bay region.

[a] Information furnished by Mr. August Bowser.

[b] Bull. U. S. Geol. Survey No. 225, 1904, pp. 380-382; Bull. U. S. Geol. Survey No. 250, 1905.

The Triassic rocks occur on Cape Kekurnoi at the eastern entrance to Cold Bay, and on some of the capes and islands to the northeast. They doubtless underlie the Jurassic throughout the Cold Bay region.

The Enochkin formation occupies both shores of Cold Bay except at the northeastern promontory (Cape Kekurnoi) and at the head of the bay. It also extends in a belt along the shore of Shelikof Strait from Cold Bay to Dry Bay and probably as far beyond as Portage Bay.

The Naknek formation forms the shore of the head of Cold Bay and occupies the entire interior region as far west as Becharof Lake and as far north as Katmai.

The post-Jurassic volcanic rocks occur in a discontinuous belt near the center of the peninsula. This belt includes several volcanoes which have been active in comparatively recent time. The lavas are probably all either andesite or basalt.

STRUCTURE.

The most striking structural features are an anticline with a northeast-southwest axis extending from a point $3\frac{1}{2}$ miles above the mouth of Oil Creek to Kanata and a syncline extending from near the mouth of Oil Creek northeastward into Cold Bay. The northern end of this syncline is cut off by a fault which extends up the valley of Dry Creek. The anticline terminates by flattening out.

The dip is quite uniformly northwestward on the north shore of Cold Bay and on the north side of Dry Creek. Along the southeastern side of Becharof Lake it is northwestward and westward. On the western shore of Cold Bay it is northwestward or horizontal. On Dry Bay it is southeastward. The dips seldom exceed 15°, except toward the mouth of the bay, and are low and regular over wide areas.

The region between Becharof Lake and the Becharof–Cold Bay divide has a uniform westward and northwestward dip. This dip is reversed again near the center of the peninsula, so that part of Becharof Lake lies in a syncline, while near its northwestern shore a sharp anticline is said to rise, which brings to the surface not only the entire sedimentary series, but also the mass of coarse crystalline rocks that form the core of the peninsula throughout most of its length. There is also a great anticline parallel to the southern coast that has its axis near the ends of the forelands.

INDICATIONS OF PETROLEUM.

SEEPAGES.

There are several seepages at the north end of the anticline near the oil wells. In all of these the flow of petroleum is large and constant. One of them furnishes lubricating oil for use at the wells. There is also a considerable flow of gas at one of these seepages.

Other seepages, not seen by the writer, are reported from various places along the crest of this same fold, near the head of Dry Bay, and elsewhere between that point and Kanata. There are said to be even more important seepages on the west shore of the south arm of Becharof Lake.

DEVELOPMENTS.

Three wells were begun in the summer of 1903. They are located about 5 miles from the landing on the west shore of Cold Bay, at an elevation of about 750 feet above tide, and are distant about 9 miles in an air line from Becharof Lake.

One of the wells begun during the summer of 1903 was abandoned in the autumn at a depth of several hundred feet, and the derrick was moved to a new site a few hundred feet distant. Very little drilling had been done at this point up to the time the writer left Alaska.

The second well was drilled to a depth of about 1,400 feet. The drill is said to have penetrated several strata filled with thick residual oil having about the consistency of warm pitch. This well was finally abandoned during the summer of 1904, because of the strong, continual flow of fresh water. It is now certain that this well is situated near a fault, which fact would seem to explain the presence of large amounts of fresh water at all depths, and also the absence of the more volatile and fluid constituents in the oil. The machinery from this well has now been moved to a new location about 2¼ miles southeastward on Trail Creek. At last reports it had reached a depth of 1,500 feet.

Record of well at Cold Bay.

	Thickness in feet.
Sandstone	76
Hard sand, with crevices	39
Sand, with hard streaks	85
Oil sand, not hard	40
Sandstone, with hard streaks	60
Oil sand, soft	8
Sandstone, with hard streaks	82
Oil sand	25
Soft, argillaceous sandstone	15
Soft, blue sandstone with oil	5
Total	435

CHARACTER OF THE OIL BAY AND COLD BAY PETROLEUM.

Samples of the oil from Oil Bay and Cold Bay have been collected by the writer. They were obtained by skimming the petroleum from the surface of the pools of water where it was continually rising from the bottom of the pool. An effort was made to obtain as much of the fresher oil as possible. Vegetable and earthy impurities were removed by straining through coarse cloth. Water could not be entirely removed. Oil for lubricating purposes at the neighboring wells is obtained from these pools in this manner.

The fresher oil is dark green. That which has remained on the surface of the pool for some time is dark brown.

The oil has doubtless lost a large part of its volatile constituents. The analyses, therefore, would not correctly represent the composition of live oil from wells in this region. Such oil would have a lower specific gravity, higher percentage of the more volatile constituents, and lower percentage of the less volatile constituents, residue, and sulphur. It would certainly be better than these samples in all respects, and would resemble them in having a paraffin base. It might not be of as high quality as the Controller Bay petroleum, but neverthless it would be a refining oil.

The samples were submitted to Penniman & Browne, of Baltimore, who return the following report on their tests:

Report of tests of oil from Oil Bay and Cold Bay.

	Oil Bay.	Cold Bay.
Specific gravity at 60° F	0.9557 (16.5° B.)	0.9547. (16.6° B.)
Distillation by Engler's method:		
Initial boiling point	230° C.	225° C.
Burning oil (distillation up to 300° C., under atmospheric pressure).	13.2 per cent (29.5° B.)	13.3 per cent. (29.6° B.)
Lubricating oils (spindle oils) (120 mm. pressure up to 300° C.)	39.2 per cent (22.6° B.)	28.3 per cent. (23.8° B.)
Lubricating oils (120 mm. pressure, 300° C.–350° C).	19.6 per cent (17.9° B.)	18.3 per cent. (18° B.)
Paraffin oils (by destructive distillation under atmospheric pressure.	22.4 per cent (20.4° B.)	32.0 per cent. (20.4° B.)
Coke and loss	5.6 per cent	8.1 per cent.
Total sulphur	0.098 per cent	0.116 per cent.

The distillation of the lubricating oils under diminished pressure, corresponding to refinery practice, was carried on until signs of decomposition set in. The resulting residue was unsuitable for making cylinder stock, and was therefore distilled for paraffin oils. These paraffin oils contain a considerable quantity of solid paraffin. It was not practicable to determine the amount of the material with the small amount of oil at our disposal.

The iodine absorption of the oils and distillates has been determined by Hanus's method (solution standing four hours) and the results are here tabulated:

Iodine absorption of oils and distillates.

	Oil Bay.	Cold Bay.
	Per cent.	*Per cent.*
Burning oil	17.8	17.2
Lubricating oil	26.2	27.2
Heavy lubricating oil	35.8	35.2

These iodine numbers upon the lubricating oils were obtained upon the samples. For comparison, samples of similar oils were obtained from the Standard Oil Company and the iodine numbers determined as follows:

Light distillated lubricating oil (spindle oil)	32 per cent iodine.
Dark lubricating oil (engine oil)	45.4 per cent iodine.

The burning oils were tested in a small lamp and found to give a good flame. All the oil was consumed without incrusting the wick or corroding the burner.

The sample of crude oil from Cold Bay was distilled in such a way as to give the maximum yield of burning oil. Under these conditions 52.2 per cent of fair quality burning oil was obtained.

The oils are entirely similar, both have paraffin bases, and the products of distillation are "sweet." We are informed that these samples are "seepage oils." If a sufficient yield can be obtained by drilling, a very suitable oil for refinery purposes may be expected, containing a very much larger quantity of the more desirable lighter products.

OTHER POSSIBLE PETROLEUM FIELDS.

Indications of petroleum have been reported from other parts of the Alaska coast, at some of which land has been staked or other investments made.

Seepages are reported from the shores of Kamishak Bay, especially at Douglas River. The rocks in this region are shales, sandstones, and conglomerates of Jurassic age. They are the equivalent in age of the beds overlying the Enochkin formation in the region to the north already described. The rocks are here horizontal or have very gentle dips over large areas, and it would seem to be a promising region to prospect with the drill. If the Middle and Lower Jurassic rocks in the Enochkin or Cold Bay regions prove to contain oil in commercial quantity it would seem that new fields might reasonably be expected on the coast at Douglas River and for 20 miles westward. This is, however, a difficult place to land machinery, for the bays are all shallow and filled with rocks, while numerous uncharted reefs extend out many miles from shore into Cook Inlet. The writer is, therefore, not inclined to encourage speculation here, at least until more encouraging news is heard from the drills already at work.

The geology of the coast between Snug Harbor and Chinitna Bay, between the east side of Enochkin Bay and Bear Bay, and between Douglas River and Katmai does not warrant in the slightest degree any petroleum prospecting. Along much of this coast are only volcanic and other crystalline rocks, in which the occurrence of petroleum is an absolute impossibility.

Petroleum seepages are reported from the shores of Kachemak Bay. There is nothing in the geology of the region to disprove the occurrence of oil on the north shore of the bay, but the author does not believe that investment would be justified, at present at least, unless it is shown beyond doubt that good seepages exist.

Seepages have been reported from various points on the Alaska Peninsula to the west of the Cold Bay region. Too little is known of the structure of this region to warrant public advice.

The indications of petroleum in the Cape Yaktag region have already been described in a previous publication. No drilling has been done in this field and there is nothing to add to the previous descriptions of the geology.

BERING RIVER COAL FIELD.

By George C. Martin.

INTRODUCTION.

The Bering River coal field is situated from 12 to 25 miles inland from Controller Bay, on the northern tributaries of Bering River and about 35 miles east of Copper River. This field has attracted considerable attention in recent years because of the very high quality of the coal and the great number and thickness of the seams. The region was hastily studied by the author during the summers of 1903 and 1904. The results of earlier work have already been published in abstract,[a] while a more complete discussion [b] together with maps is in press. The latter, although based primarily upon the field work of 1903, has been revised in proof since the close of the field season of 1904. The following pages are hence in part a duplication of the chapter on coal in Bulletin 250. The writer has attempted to present the purely economic facts more clearly in the following pages than was possible with the limited amount of revision allowed in the other publication. Facts other than economic will be found more fully presented in Bulletin 250.

Since the passage of the law providing for the survey and sale of coal lands in Alaska there has been renewed activity in the development of this field. The construction of many miles of trails and of upward of a hundred new prospect openings made it possible for the writer, during a brief visit to the field in the autumn of 1904, to gather many new facts concerning the geology and coal deposits of the region. The result not only confirms the earlier favorable opinion of the field, but proves that the amount of coal is far greater than was hitherto suspected.

GEOLOGY.

The coal area now known is situated entirely within the valley of Bering River and on the northern tributaries of that stream (fig. 8). The southern or coastward boundary of the coal area coincides with the position of Bering River and Bering Lake. The western boundary probably lies along a north-south line extending through the northern

[a] Petroleum fields of Alaska and the Bering River coal field: Bull. U. S. Geol. Survey No. 225, 1904, pp. 365-382.

[b] The petroleum fields of the Pacific coast of Alaska, with a description of the Bering River coal deposits: Bull. U. S. Geol. Survey No. 250, 1905.

rm of Bering Lake. The coal is known to extend as far northward s the Martin River Glacier and as far eastward as the valley east of Carbon Mountain. This area includes about 120 square miles. It is possible that further exploration will reveal the presence of coal north of Martin River Glacier in the foothills of the Chugach Mountains, or in the region to the east of Carbon Mountain.

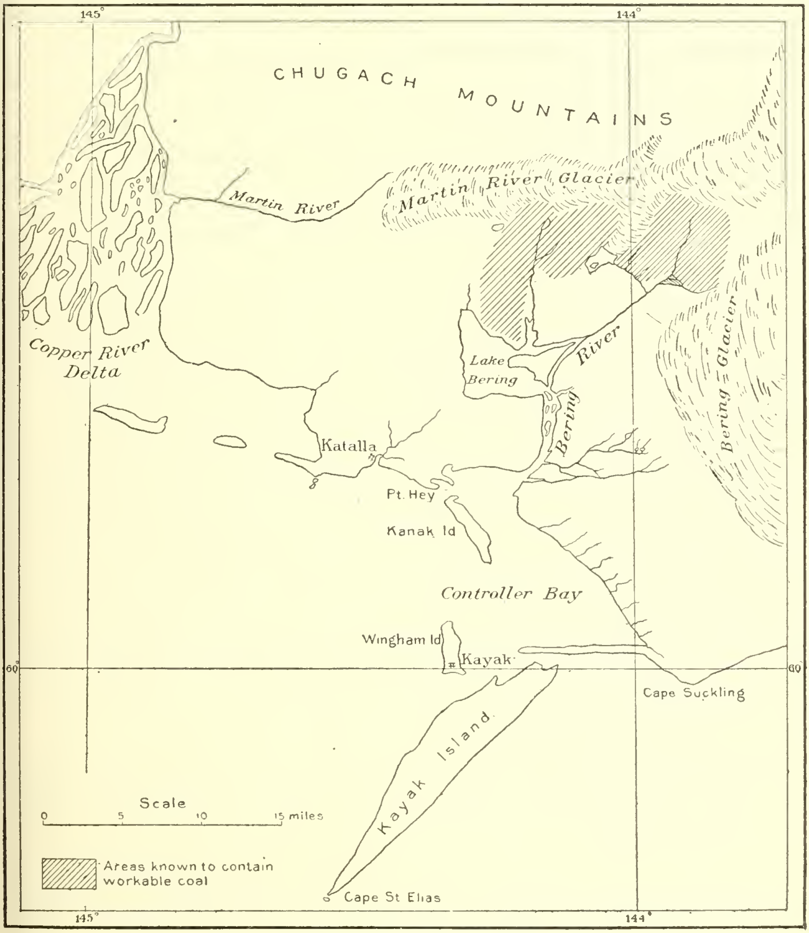


FIG. 8.—Sketch map of Bering River coal field.

The lowlands bordering the northeast shore of Bering Lake and extending for a considerable distance up the valleys of Shepherd Creek, Bering River, and other streams are doubtless underlain with coal. The covering of mud and other soft deposits is probably very thick, and the uncertainties of deep mining below it are so great that these lands must now be regarded as of very doubtful value. The same applies to the region covered by the Bering, Martin River, and Kushtaka glaciers (fig. 8). The estimates given above of the coal area

include, therefore, only the high land lying above and between the tidal flats and river flats and the glaciers.

The coal-bearing rocks have been designated by the writer as the Kushtaka formation, which contains fossil plants of supposed Oligocene age, and is the probable equivalent of at least part of the Kenai formation of the Cook Inlet region. This formation has the areal extent described above and is adjoined on the south by the Katalla formation, which it probably overlies. Its areal and structural relation to other formations to the west, north, and east is not known.

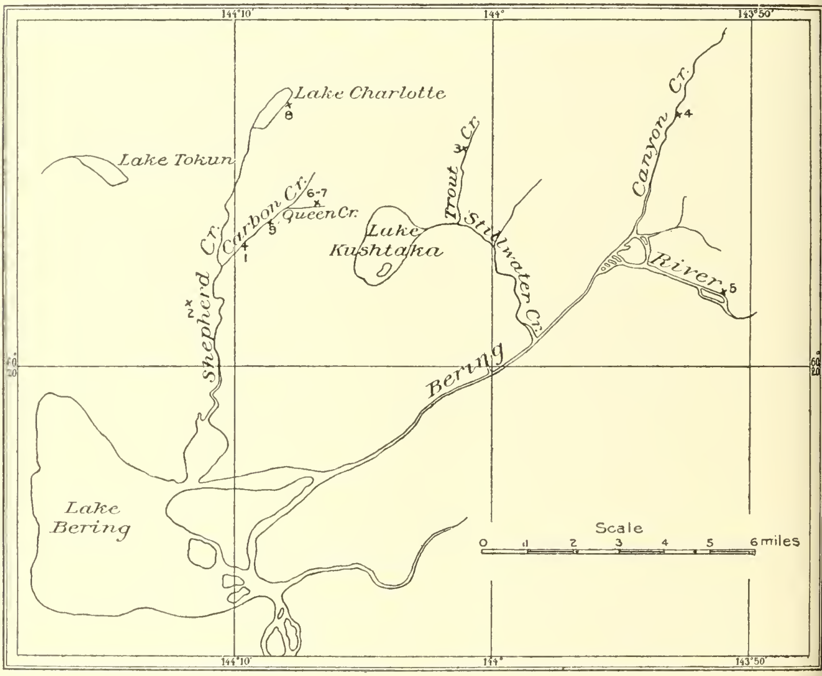


FIG. 9.—Sketch map of Bering River coal field, showing location of openings from which samples of coal analyzed were obtained.

The Kushtaka formation consists of probably several thousand feet of sandstone, shales, arkose, and volcanic ash, with many coal seams.

The prevailing strike over the greater part of the coal-bearing area is about N. 40° E. The prevailing dip is northwest at an angle of about 45°. This monoclinal dip is apparently modified by only two folds within the region now known. There is at least one fault of considerable length and displacement, and several smaller ones.

One of these folds is an anticline exposed near the headwaters of Queen Creek (fig. 9) on the divide between the Shepherd Creek and Lake Kushtaka valleys. The rocks here have a strike of N. 64° to 66° E., with a northwest dip of 42° on the northwest flank of the fold

and a southeast dip of 58° on the southeast flank. The latter is cut by a fault of unknown but probably considerable magnitude. The other fold is a sharp syncline which apparently lies in the hills east of Lake Charlotte. Its presence is indicated by the fact that the dip of the Charlotte seam at the openings above the lake (fig. 9) is southward. It is not known how far in either direction this southeast dip continues.

COAL SEAMS.

Several valuable seams have recently been opened in the valley of Canyon Creek and on the opposite (east) side of Carbon Mountain. It is said that of fifteen openings in the same seam on Carbon Mountain which showed a range of thickness from 9 to 25 feet, nine openings revealed a thickness of 14 feet or more. About a dozen workable seams have been reported from this region. The writer has already published the following sections of the coal and coke seen by him in this vicinity,[a] those described above not having been opened at the time of his visit in 1903.

Four seams are exposed on the east bank of Canyon Creek. Three miles above the mouth a seam has a thickness of 2 feet 9 inches, is overlain by sandstone, and has a shale floor. The strike is N. 80° E., the dip westward at an angle of 35°. The section was measured at the level of the valley bottom. This seam is variable in thickness, pinching out somewhat higher in the bluff.

Four miles above the mouth of Canyon Creek (fig. 9) a seam has a thickness of 4 feet 2 inches; it strikes N. 10° E. and dips westward at an angle of 60° and has a shale roof and floor.

At the south end of Carbon Mountain there is a high bluff, where Bering River has been pushed against the end of the mountain by the Bering Glacier, and here the following section was measured:

Section at south end of Carbon Mountain, Alaska.

	Feet.
Sandstone	30
Coke	1
Sandstone	20
Coke	2
Sandstone	2 to 5
Coke	1 to 5
Sandstone	3
Coke	1
Sandstone	8
Coke	$1\frac{3}{4}$ to $2\frac{1}{4}$

The strike at this point is N. 80° W., the dip is northward at angles ranging from 20° to 25°.

The valley of Stillwater Creek and Lake Kushtaka has been shown to contain a great deal of valuable coal. A trail recently built northward from the western shore of Lake Kushtaka exposes 15 or 16

[a] Bull. U. S. Geol. Survey No. 225, 1904, p. 372.

seams. The writer has seen one seam on the west side of Lake Kushtaka, which has a thickness of over 22 feet, and several others with thicknesses of from 8 to 15 feet. It is reported that a thickness of over 60 feet of coal was found in a tunnel in one of the valleys on the north side of Stillwater Creek. This was not exposed at the time of the writer's visit in 1903, but the following section was measured in the west bank of Trout Creek, 2 miles above its juncture with Stillwater Creek and 6 miles above the mouth of the latter (fig. 9):

Section on Trout Creek.

	Feet.
Shale	4
Coal	6½
Sandstone	5

The strike is N. 40° E.; the dip is west at an angle of 38°.

The high ridge between Lake Kushtaka and Shepherd Creek contains a large number of seams. Probably, at least twenty of these seams are 5 feet or more in thickness, and several are over 20 feet thick.

The western slope of this region is drained by Queen Creek and other branches of Carbon Creek. Queen Creek has cut into the crest

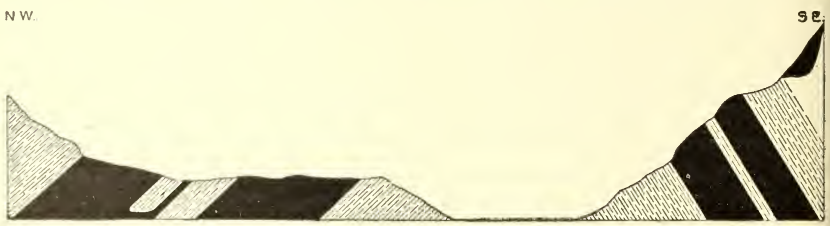


FIG. 10.—Section of coal seams on Queen Creek. Scale, 1 inch=75 feet.

of a sharp anticline, which is probably faulted on its southeastern flank, and on both flanks of which coal seams are exposed. The coals in this locality are of extraordinary thickness, perhaps having swollen into pockets near the crest of the fold (fig. 10).

Section of coal on northwest bank of Queen Creek.

	Feet.
Shale roof.	
Coal	27
Shale (pocket?)	7
Coal	2
Shale	10
Coal	31
Shale floor.	

Section of coal on southeast bank of Queen Creek.

	Ft.	in.
Coal	14	0
Shale	4	0
Coal	7	0
Shale	0	3
Coal	2	0
Shale	0	2
Coal	10	0

Several prospect openings and two tunnels have been driven into he banks of Carbon Creek (fig. 9). One of the tunnels intersects two eams, the larger of which has a thickness of 8 feet of clean coal. 'his is not the same as the Carbon Creek tunnel mentioned by the vriter[a] in previous publications, and also below. The latter is about mile below this and cuts a seam 20 feet thick.

Section in lower tunnel on east bank of Carbon Creek.

	Feet.
ark shale	2
'oal	20
Iassive, arkosic, cross-bedded sandstone, with many thin carbonaceous streaks.	10

The strike at this point is N. 65° E.; seam dips northwest at an ngle of 60° at the roof and at an angle of 78° at the floor.

The valley of Shepherd Creek above the mouth of Carbon Creek as been more extensively prospected of late and proves to contain aluable coal. The $20\frac{1}{2}$-foot seam at "Doyle camp," mentioned by ie writer in an earlier publication, has been found to be cut off by a ult at the prospect opening and is of doubtful extent. Several naller seams have been opened recently, of which the most promis- ig is the Charlotte seam, on the hillside southeast of Lake Charlotte ig. 9).

Section of Charlotte seam.

	Ft.	in.
ale roof	10+	
oal	0	2
ale	0	5
oal	9	6
ale and coal	6	0

The strike of the seam is N. 12° E.; the dip is eastward at an angle f 72°. The same seam has been opened again about half a mile south of is point. The coal in this seam is firmer and should stand shipment ith less crushing than any other seen by the writer in this field, but one opening, at least, the amount of ash is excessive.

The following section was measured in the lower part of the Shep- erd Creek Valley (fig. 9):

Section 1 mile northwest of Canoe Landing on Shepherd Creek.

	Ft.	in.
oal	3	0
ale	0	2
oal	4	4

The strike at this point is N. 20° E.; the dip is northwest at an igle of 65°. The opening is on the west side of the valley of Shep- erd Creek, at an elevation of about 200 feet above Bering Lake.

The region adjoining the north shore of Bering Lake had been cploited to a considerable extent during the past season and a small nount of coal mined for local use. The seams so far discovered in this gion are smaller than those described from other parts of the field.

[a] Bull. U. S. Geol. Survey No. 225, 1904, p. 372.

CHARACTER OF THE COAL.

The physical properties of the coal are very much alike in all th seams and in all parts of the field visited by the writer. The coa resembles the harder bituminous coals of the East more than it doe anthracite. It is doubtful, too, if much of the coal could be sized s as to compete with anthracite coal for domestic use. Furthermore under ordinary handling it will probably crush to almost the sam extent as the harder grades of semibituminous coal; this will no seriously impair its value for steam purposes, but will necessitat very careful handling if it is to compete with Pennsylvania or Wels anthracite as a domestic fuel.

The following table includes all the available analyses and calori metric tests which have been made upon the Bering River coal. Th first nine samples were collected by the author and represent the com position of the entire seam; that is, coal was cut evenly from the sean from roof to floor.

Analyses and tests of Bering River coals.

Locality.	Thickness of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Color of ash.	Calories.	Recalculated. Fuel elements. Volatile matter.	Fixed carbon.	Fuel ratio.
	Ft.										
1. Carbon Creek (lower tunnel. [a]	20	2.41	15.03	79.24	3.32	0.51	Reddish..	8,345	15.94	84.06	5.2
2. Shepherd Creek [a]..	$7\frac{1}{3}$	1.54	14.58	72.99	10.89	.69	Yellow ...	7,664	16.65	83.35	5.0
3. Trout Creek [a]......	$6\frac{1}{2}$	2.36	18.12	71.87	7.65	.73	Reddish ..	7,819	20.14	79.86	3.9
4. Canyon Creek [a]....	$4\frac{1}{6}$	3.24	9.79	62.97	24.00	1.94	Yellow ...	6,502	13.45	86.55	6.4
5. South end of Carbon Mt. (coke). [a]	5	1.34	6.30	84.57	7.79	.77	Very red..	7,776	6.93	93.07	13.4
6. Queen Creek [b].....	31	1.20	17.28	77.69	3.83	.78	Reddish ..	*8,310	18.20	81.80	4.
7. Queen Creek [b].....	27	.56	16.61	78.71	4.12	1.25	Reddish ..	*8,310	17.43	82.57	4.
8. Lake Charlotte [b]...	$9\frac{1}{2}$	.68	17.87	60.73	20.72	.55	Grey......	*6,883	22.74	77.26	3.
9. Carbon Creek (upper tunnel). [b]	8	.38	16.97	77.48	5.17	1.02	Grey......	*8,248	17,97	82.03	4.
10. Bering River [c].....	....	.83	7.18	87.57	4.42	......	....	....	7.58	92.42	12.
11. Bering River [d].....	....	1.00	14.30	81.10	3.60	......	....	....	14.99	85.01	5.
12. Controller Bay [e]...	....	.75	13.25	82.40	3.60	.69	....	*8,376	13.85	86.15	6.
13. Controller Bay [e]...	....	.78	13.22	80.30	5.70	2.90	....	*8,043	14.13	85.86	6.
14. Bering River [f].....	....	.77	13.79	82.36	3.08	2.68	Brownish.	*8,289	14.34	86.66	5.

[a] Sample collected by G. C. Martin. Analysis and calorimeter test by Penniman and Browne.
[b] Sample collected by G. C. Martin. Analysis by E. C. Sullivan.
[c] Analysis by William H. Fuller, Fairhaven, Wash. Published by John Kirsopp, jr., in paper on T coal fields of Cook Inlet, Alaska, U. S. A., and the Pacific Coast: Trans. Inst. Min. Eng., vol. 1901, page 537.
[d] Analysis by W. F. Robertson, Victoria, B. C. Published by John Kirsopp, jr., as above.
[e] Analysis furnished by F. H. Shepherd. Published by J. E. Spurr: A reconnaissance in sou western Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 263. (No. 13 is not from Icy B as hitherto reported.)
[f] Sample collected by W. M. Carless. Analysis by W. F. Hildebrand. Published by Schrader a Spencer, Geology and Mineral Resources of a Portion of the Copper River District, Alaska, p. 91.
* Calories computed.

NOTE.—The location of the openings from which samples 1 to 9 were taken is shown by the numb on the map. (Fig. 9.)

Analyses of other coals for comparison.

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	B. T. U.	Recalculated.		
								Fuel elements.		Fuel ratio.
								Volatile matter.	Fixed carbon.	
Pennsylvania, anthracite (average of 9)[a]	3.385	3.812	83.790	8.417	0.592	......	......	4.35	95.65	21.99
Wales, anthracite (average of 4)[b]	......	5.94	91.42	2.62	......	......	......	6.11	93.89	15.80
Loyalsock, semianthracite (average of 4)[c]	1.488	11.074	78.883	7.695	.861	......	......	12.31	87.69	7.12
Pocahontas, semibituminous (average of 38)[d]	.73	17.43	77.71	4.63	.62	8,403	15,178	18.32	81.68	4.46
Georges Creek, semibituminous (average of 12)[e]	.69	18.95	74.11	6.08	.67	7,984	......	20.36	79.64	3.91
Pocahontas, (Quinnemont), semibituminous (average of 17)[f]	.60	19.93	75.20	4.27	.67	8,415	15,202	20.95	79.05	3.77
New South Wales (southern coal fields), bituminous (average of 21)[g]	.97	23.10	65.26	10.67	.462	......	......	26.14	73.86	2.83
Wales bituminous (average of 37)[h]	......	27.00	68.09	3.22	1.43	8,402	......	28.39	71.61	2.52
Comox, bituminous (average of 4)[i]	1.30	28.63	62.73	6.96	......	......	......	31.35	68.65	2.19
Naniamo, bituminous (average of 4)[i]	2.19	30.76	56.52	10.53	......	......	......	35.24	64.76	1.84
New South Wales (western coal field), bituminous (average of 13)[g]	1.87	31.49	52.61	14.03	.626	......	......	37.44	62.56	1.67
New South Wales (northern coal field), bituminous (average of 77)[g]	1.92	35.09	54.08	8.91	.541	......	......	38.23	61.77	1.62

[a] Ashburner, C. A., Ann. Rept. Geol. Survey Pennsylvania, 1885, p. 313.
[b] Lozé, Ed., Les Charbons Britanniques et leur Epuisement, vol. 1, p. 386.
[c] Ashburner, C. A., Ann. Rept. Geol. Survey Pennsylvania, 1885, p. 318.
[d] White, I. C., Geol. Survey West Virginia, vol. 2, pp. 695, 696, 700.
[e] These are furnished by W. B. Clark, State geologist of Maryland, and will be published in a forthcoming report of the Maryland geological survey on the coal of that State.
[f] White, I. C., Geol. Survey West Virginia, vol. 2, p. 670.
[g] Pittman, E. F., Mineral Resources of New South Wales, 1901, pp. 324-348.
[h] Poole, H., The Calorific Power of Fuels, 1898, p. 223
[i] Dawson, G. M., Mineral wealth of British Columbia: Geol. Nat. Hist. Survey Canada, new ser., vol. 3, pt. 2, p. 98 R.

The above coals vary greatly in composition and in heating power, and it seems likely that in this field, as everywhere, each seam will be found to have a characteristic composition.

If these analyses are grouped and each group averaged they become more significant. Samples 1, 6, 7, and 9 were all taken by the writer from four different seams in a somewhat restricted area. The range of variation in this group is small, all being extremely pure as regards both ash and sulphur, and all have a fairly high content of fixed carbon with a low content of volatile hydrocarbons and consequently fairly high fuel ratio and heating value.

Average of analyses 1, 6, 7, and 9.

Moisture	1.14
Volatile hydrocarbons	16.47
Fixed carbon	78.28

Ash	4.11
Sulphur	.89
Fuel ratio	4.70
Calories (computed in part)	8,303

These coals are intermediate in fuel ratio between the Bernice basin or Loyalsock (Pennsylvania) semianthracite and the Pocahontas (West Virginia) semibituminous. They are purer and have a higher heating power than the Loyalsock coal, although they lack its anthracitic physical characteristics and have a lower fuel ratio. They are almost identical in heating power, as well as in the low amount of impurities, with the Pocahontas steam coal of West Virginia, but excel this coal by having a higher proportion of fixed carbon. These coals can not be compared with any other coal with which they are likely to come into general competition for they are far higher in heating power and in purity than any coal mined upon the Pacific coast, either in the United States, in British Columbia, or in Australia.

Samples 2 and 3, from openings 1 mile northwest of Canoe Landing on Shepherd Creek, and from near the headwaters of Trout Creek, are probably representative of the thinner seams of this region.

Average of analyses 2 and 3.

Moisture	1.95
Volatile hydrocarbons	16.35
Fixed carbon	72.43
Ash	9.27
Sulphur	.71
Fuel ratio	4.49
Calories	7,742

These coals differ from the coal of the thicker seams discussed above in having a less amount of fixed carbon in proportion to the volatile matter and in having a higher percentage of ash and sulphur. The heating power is consequently less. Nevertheless, they resemble coals of the semibituminous type that enter the market as high-grade steam coals. They correspond in texture, composition, and heating power to the high-grade Pocahontas (West Virginia) and Georges Creek (Maryland) steam coals, and also to some of the semibituminous coals of Wales.

The analyses of which the average is given in the following table were obtained from various sources (see p. 146).

Average of analyses 11–14.

Moisture	.82
Volatile hydrocarbons	13.64
Fixed carbon	81.54
Ash	3.99
Sulphur	2.09
Fuel ratio	5.98
Calories (computed)	8,236

These analyses, although obtained from various sources, correspond so closely that the writer regards them as probably fair representatives of some seam or group of seams which he did not sample. Two of these coals contain excessive amounts of sulphur, which carry the average abnormally high. Otherwise they are of better quality, especially as regards the fuel ratio, than the coal discussed above. It may be that they were picked samples that did not represent the entire thickness of the seam, in which case the high percentage of sulphur is probably due to their having been taken from pieces of coal which were picked for their hardness and apparent cleanness. The one who took the samples evidently overlooked the fact that their exceptional hardness was not due to the coal being nearer anthracite, but to its containing a large amount of pyrite (sulphide of iron).

The following table is the average of all the analyses quoted in the general table (see p. 146) with the exception of No. 5, which is not coal, but natural coke, and No. 10. The latter differs from all the others so much that it can not be considered representative, and if it is authentic it probably represents either a far outlying district or an outcrop of the natural coke.

Average of 12 analyses.

Moisture	1.306
Volatile hydrocarbons	15.068
Fixed carbon	75.653
Ash	7.974
Sulphur	1.249
Fuel ratio	5.151
Calories (in part computed)	7,890

In this average even the analyses from the impure seams 4 and 8 are included, although these will probably not be mined. In spite of the fact that these are included it may be seen that the general average represents a coal of more than average purity and high heating power.

DEVELOPMENT.

The work which has been done in the development of this field is entirely pioneer development work. Land surveys have been made of some of the larger holdings. Several railway routes have been surveyed. Many miles of good trails have been built, and a large number of cabins erected. Many prospect openings have been made and several more extensive tunnels dug. There is a tramroad and a gravity plane from the west bank of Shepherd Creek to a tunnel on the hillside to the west. A small amount of coal is being mined for local use in stoves and as blacksmith coal at some of the neighboring oil wells. More extensive mining will be delayed until shipping facilities are provided at Controller Bay or elsewhere and a railroad is built from the harbor to the mines.

The lands in this region that are known to be coal bearing have fo the most part, if not entirely, been located, and it is understood tha some of the holders are about to secure patents. It seems probabl that there are unlocated coal lands in the unexplored area to the eas and northeast.

The features to be considered by the investor and mining enginee embrace faults and their attendant problems, including the questio of local pockets; steep dips, the proportion of the seams above wate level, accessibility, and the physical properties of the coal as affectin its shipment and market value, a tendency to crush being especiall noticeable.

One of the most serious of these is the question as to how much th thickness appearing at the present openings may represent loc expansion of the seams. This question can not be finally answere without extensive underground exploration. Nevertheless, there little doubt that the extremely great thicknesses (25 to 60 feet) repr sent pocket swellings and are of limited extent. Almost all suc great thicknesses as known in other fields occur in local pockets, an most fields with a structure like this have such pockets. But in spi of this there is little doubt that there are many seams which will prov to be of workable thickness over large areas, and several seams whic will have average thicknesses of from 10 to 20 feet. The amount coal, even above drainage level, is enormous.

The shipping problems are serious, but the amount and quality the coal would seem to be sufficient to justify large initial expend tures. It will, however, require strong companies to develop th field.

COAL RESOURCES OF SOUTHWESTERN ALASKA.

By Ralph W. Stone.

INTRODUCTION.

Southwestern Alaska includes the Cook Inlet region, Kodiak and adjacent islands, Alaska Peninsula, and the Aleutian Islands. Coal, mostly of a lignitic character, is widely distributed in this province. The known localities are indicated on the accompanying map (Pl. II). Coal-bearing rocks occur in three principal districts, Cook Inlet, Kodiak Island, and Alaska Peninsula. In Cook Inlet coal is found at Kachemak Bay and Port Graham on Kenai Peninsula, at Tyonok on the west shore, and on Matanuska River about 50 miles inland from the head of the inlet. It has also been reported at various localities in the Sushitna basin, which lies beyond the province under discussion. Coal occurs at several points on the shore of Kodiak Island. From Cape Douglas, at the northern end of Alaska Peninsula, out to the Aleutian Islands coal-bearing beds are found at several places, but Chignik and Herendeen bays and Unga Island are the only localities where developments have been made.

The earliest accounts of any of these coal beds are those of Portlock[a] who made a voyage to Alaska in 1786, and of Doroshin and Wosnessenski,[b] Russian mining engineers and explorers. In 1895 W. H. Dall made a coast trip in southern Alaska and reported on the coal.[c] Mining operations were then being carried on at Kachemak and Chignik bays and Unga Island, but are now confined to Chignik Bay.

During the summer of 1904 the writer, acting under orders of G. C. Martin, had an opportunity to examine several of the coal localities on the east coast of the Alaska Peninsula and about Cook Inlet. The result of these investigations, together with information concerning some localities which the writer did not visit, and a report on the lignite at Unga by G. C. Martin, are embodied in this report.

[a] Portlock, Nathaniel, A Voyage to the Northwest Coast of America, London, 1789.

[b] Grewingk, Constantin, Beitrag zur Kenntniss N. W.-Küste Am., 1850, pp. 39–41; and Wrangell, in Baer and Helmersen, Beiträge I, 168–170.

[c] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 784–814.

Acknowledgments are due S. T. Penberthy, of Homer; E. G. Wharf, of Seldovia; James Casey, of Cold Bay; G. M. Landsburg and J. L. Wetherbee, of Chignik; and Captain Morris, of the steamer *Dora*, for courtesies and assistance.

GEOLOGY.

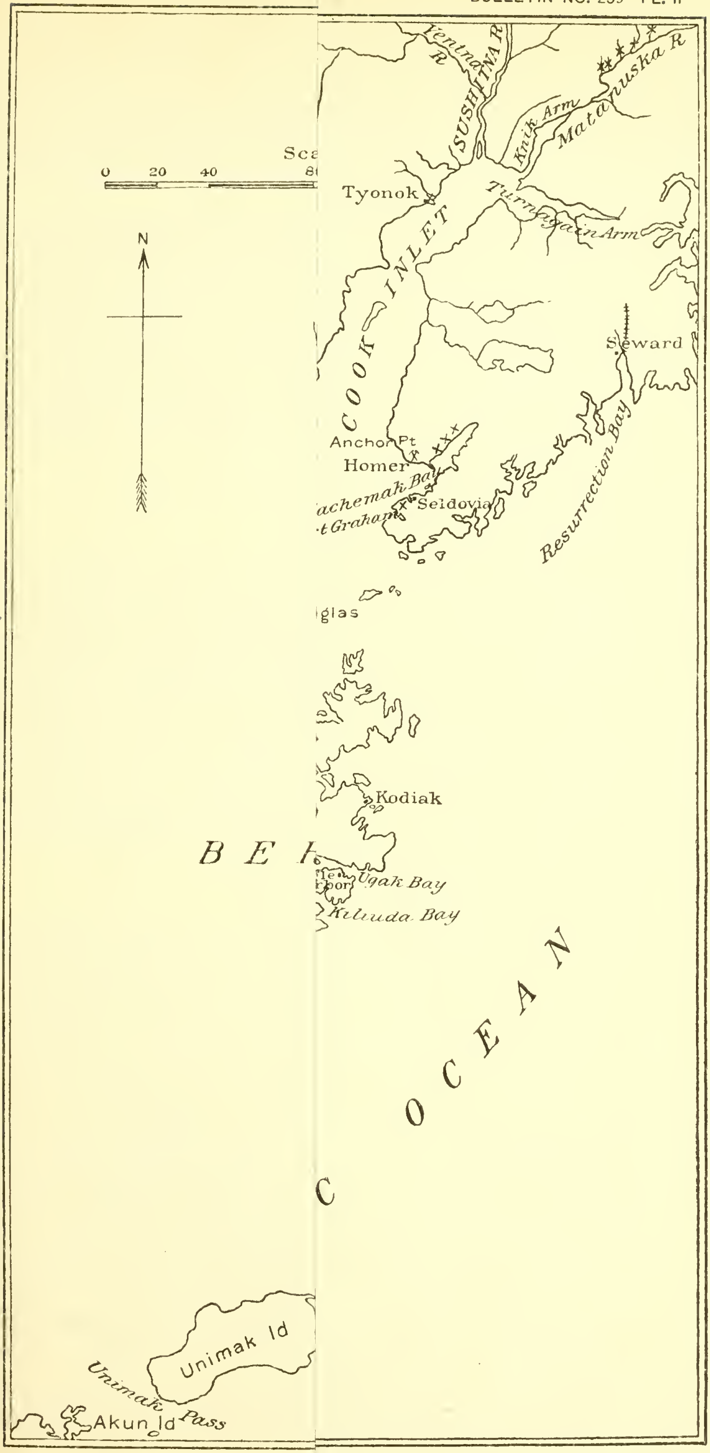
The backbone of Kenai Peninsula consists of sedimentary rocks, and the backbone of Alaska Peninsula of crystalline and metamorphic rocks with a considerable quantity of volcanics. At frequent intervals along the coast there are more or less extensive areas of partially or wholly consolidated sedimentary rocks, which range from Triassic to Tertiary in age. A formation composed of sandstone, fine conglomerate, shale, and clay, with interstratified coal seams, is found on the east side and at the head of Cook Inlet, on Kodiak Island, and at a number of points on Alaska Peninsula. The coal-bearing series at Kachemak Bay, Port Graham, Tyonok, Kodiak, and Unga are all thought to belong in the Kenai formation, which is Oligocene; while the Matanuska coal beds have been tentatively referred to the Lower Cretaceous. It is a question whether the coals at Chignik and Herendeen bays are Tertiary or Cretaceous. There are possibly two coal-bearing formations in this district.

The coal of southwestern Alaska is mostly lignite. Some of it, however, may grade as bituminous, while some is brown coal.

DEVELOPMENT.

Probably the earliest exploitation of coal in southwestern Alaska was that of the Russians at Port Graham. In April, 1855, the bark *Cyane*, Captain Kinzie, took miners and machinery from San Francisco to this bay. Mining operations continued about ten years and supplied Russian steamers with coal. A company organized in 1889 to mine and ship coal from Herendeen Bay failed to develop a successful mine. Several companies have since tried the same thing in this field, but without success. At Unga mining in a small way to supply local needs has been done at intervals for twenty years. The Alaska Packers' Association opened a mine at Chignik in 1893 and has operated it continuously to the present time.

Coal was mined in Kachemak Bay for the first time in 1891, when Lieut. R. P. Schwerin, U. S. Navy, took 200 tons from McNeil Canyon. Two San Francisco companies began operations in this coal field about 1894, and for three years continued mining in McNeil and Eastland canyons. In the fall of 1899 the Cook Inlet Coal Fields Company undertook to mine coal in the bluffs on the west side of Homer spit, Kachemak Bay. During the two years following more development work was done here than has yet been attempted in any other Alaska coal field. Three tunnels and two shafts were driven, a rail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Kiluda Bay
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Unimak Pass
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SKETCH MAP OF SOUTHWESTERN ALASKA.

road 7 miles long, and a dock were built. Work ceased, however, in March, 1902.

In the summer of 1904 Chignik River was the only place in southwestern Alaska where coal was being mined. Bunkers were being built at Unga, however, preparatory to increased output from that field.

The production of this entire field to date may be roughly estimated at 10,000 tons. This does not include what the Russians took from Port Graham half a century ago. Coal is produced at the Chignik mine for about $3.75 a ton, and has to compete with better coal which can be bought in Puget Sound for $5 and brought up as ballast in the company's ships. Kachemak Bay coal has sold at the Homer dock for $5 and $6. Wellington coal brings $12 at Unalaska and Valdez.

DESCRIPTION OF LOCALITIES.

INTRODUCTION.

The coal fields will be described in geographic order from the head of Cook Inlet to the Aleutian Islands. Those which have some commercial value are at Matanuska, Tyonok, Kachemak Bay, Port Graham, Chignik River, Herendeen Bay, and Unga. Three of these, however, have serious drawbacks: Tyonok coal is of very low grade, the Port Graham beds are at or below high tide, and the Herendeen Bay field is badly faulted and possibly very limited. The localities which the writer examined are Kachemak Bay, Port Graham, coast of Alaska Peninsula from Cape Douglas to Cold Bay, and Chignik Bay.

MATANUSKA RIVER.

Within the past two or three years prospectors have reported the existence of thick seams of coal on the Matanuska River. Matanuska River flows from the east into Knik Arm, the most northerly branch of Cook Inlet. Mendenhall visited the locality in 1898 and reported the presence of a few thin seams of bright, hard coal.[a] More definite information has been obtained from George Jamme, jr., a mining engineer from Seattle, who examined the field in July, 1904.

The Matanuska coal fields lie about 30 miles beyond the head of Cook Inlet, on the north bank of Matanuska River, and extend in an easterly direction from Moose Creek for a distance of 30 miles, embracing an area of about 60 square miles. The coal measures occupy the space between the river and the hills to the north, and strike in a northeasterly direction parallel with the river. The dip is northward at angles ranging from 10° to 85°, increasing toward the north. The

[a] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 324.

formation in which the coal beds are contained consists of sandstone, slate, and shale. Concerning the structure Mendenhall says:[a]

> The Matanuska River flows nearly along the strike of the series, although both strike and dip exhibit great local variations. The former is generally about N. 60° or 70° E., and the latter is to the northwest at various angles. * * * The beds are everywhere full of small faults, as though folded under slight load.

On the basis of a few fossils found in Bubb Creek, the rocks associated with the coal have been tentatively referred by T. W. Stanton to the Lower Cretaceous, but their age has not been definitely determined.

A number of creeks tributary to the Matanuska from the north are said to intersect the coal beds. On Moose Creek an exposure of 5 feet of clean coal is reported, and on Eska and Young two seams each 6 feet thick. On King Creek a 10-foot and a 6-foot seam are said to be exposed. Probably the largest seams of coal are on Chickaloon Creek, where five beds, 5 to 35 feet thick, are reported.

The coal ranges apparently from lignite to bituminous. It is bright black in color, has conchoidal fracture, but is friable and will not stand severe handling. It burns well in an open fire, and Jamme says that he made excellent coke in a miniature oven. A small specimen in the writer's possession is granular, having a crushed appearance, and crumbles easily.

An analysis of an air-dried sample of coal from the Matanuska River field is given on page 170.

TYONOK.

A brown lignite of inferior quality occurs in the bluffs at Tyonok near the head of Cook Inlet. The inland extension of the coal-bearing formation is covered by gravel. Eldridge infers[b] that the Tyonok field extends for several miles inland and from a point 7 or 8 miles west of Tyonok along the coast as far northward at least as Theodore River. The section in the beach bluff is composed of sandstone, shale, and coal seams which dip southeast at angles ranging from 35° to 60°. The general strike of the beds, north-northeast, would carry the strata to a point about 10 miles up the Chulitna, where coal is reported. Thirty-six seams, large and small, are exposed along the beach of Tyonok, but it is possible that some are repetitions by faulting. They vary in thickness from 1 foot to 15 feet, many of them being from 4 to 6 feet thick. Not only is the coal poor grade, but the seams are much broken by clay and sandstone partings. There are three or four seams in which one or two 3-foot benches of moderately clear coal might be found.

[a] Op. cit., p. 308.

[b] Eldridge, G. H., A reconnaissance in the Sushitna Basin and adjacent territory, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 21.

The Tyonok coal is a low-grade lignite, which in appearance is often ardly more than a mass of carbonized wood. An average of four nalyses which represent the Tyonok coal at its best, and in no instance he average of a seam, shows less than 31 per cent fixed carbon. Nevertheless it is of some value, as coal from this point is the prinipal fuel used by the steamer *Tyonic*, which plies in Cook Inlet.

KACHEMAK BAY.

Kachemak Bay, an arm of Cook Inlet, 25 miles long and from 3 to 0 miles wide, indents the western side of Kenai Peninsula. A low, arrow point 4 miles long extends out into the bay near its entrance. he seaward end of this spit is the site of Homer, a post-office and teamer landing. The accompanying sketch map (Pl. III), shows the orm of the bay. It extends inland in a northeast direction, growing arrower toward the head. The north shore is comparatively smooth, while the eastern and southern shore is made irregular by coves, headands, and islands. A great plateau having a general elevation of 1,000 eet lies north of the bay, and the north shore is a bluff which varies n height from 50 to 400 feet. The bluff is cut by canyons at a numer of places between Homer spit and the head of the bay. On the outh side of the bay is a mass of rugged mountains, with six glaciers. Large vessels can go up to Bear Cove, although the head of the bay nd the north shore are very shallow. The tidal range is from 16 to 8 feet at Homer.

The geology as well as the topography of the two sides of Kachemak Bay presents strong contrasts. Crystalline or schistose rocks compose he mountains on the south side. On the north side of the bay is an xtensive Tertiary lignite-bearing series known as the Kenai formaion. From Anchor Point to the head of the bay, a distance of 40 miles, coal seams are almost continuously exposed, interbedded in soft andstone, shale, clay, and fine conglomerate. These rocks strike early east (mag.), and dip northward at angles as high, in places, as 0°. A thickness of between 2,000 and 3,000 feet of strata is exposed n the sea bluff from Anchor Point to the head of the bay. It is mpossible to determine the exact thickness because there are stretches ver which the beds can not be traced, and faults of unknown throw isturb the strata. Anchor Point is near the base of the series, but he head of the bay probably does not reach to the top, for coal has een found 15 miles farther inland.

COAL BEDS WEST OF HOMER SPIT.

The westernmost coal seams in this bay outcrop between tide levels alf a mile south of Anchor Point, while the first exposures above igh-tide level are 3 miles southeast of the point near the mouth of Travers Creek or Troublesome Gulch. A seam at this locality is said

to be about 5 feet thick, of which the middle portion is very hard and shiny. Some chunks of it will melt and coke like bituminous coal when put on the fire.

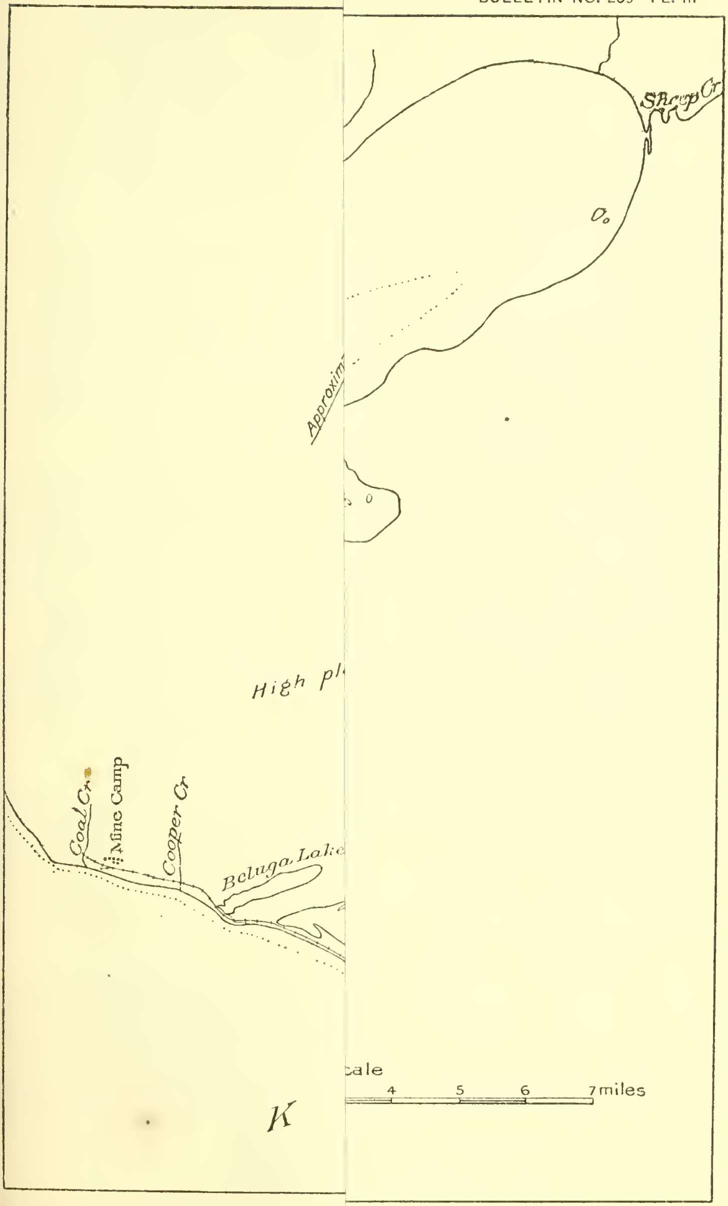
In the cliff at Bluff Point, 471 feet of strata contain 18 feet of coal in seams ranging in thickness from 3 inches to $4\frac{1}{2}$ feet. The character of the series is shown by a typical section measured near the mine camp at the west end of the Cook Inlet Coal Fields Company Railroad.

Section of Kenai formation at Mine Camp, Kachemak Bay.

	Thickness.			Thickness.	
	Ft.	*in.*		*Ft.*	*in.*
Sandstone	30	0	Clay shale	3	7
Clay shale	25	0	Coal	0	5
Coal	7	5	Clay shale	12	0
Clay shale	30	0	Coal	0	5
Coal (sample 3)	2	9	Clay shale	26	0
Shale	16	0	Sandstone	40	0
Sandstone	20	0	Clay shale and coal streaks	18	0
Coal	2	5	Coal	1	11
Clay shale	9	1	Clay shale	34	0
Coal	1	5	Sandstone	2	0
Clay shale	15	3	Coal	0	10
Sandstone	11	10	Sandstone to beach	50	0
Clay shale	16	0	Total	382	10
Coal (Cooper seam, sample 4)	6	6			

In this section there are 9 coal seams, having a total thickness of 24 feet. The smallest seam in the section is 5 inches and the largest 7 feet 5 inches. The rocks dip slightly to the east along the shore and at an angle of 15° or 20° into the bluff. It is at this point that the greatest amount of development work has been done.

The Cook Inlet Coal Fields Company chose this as the best portion of the field for developing a large mine, and began extensive operations in 1899. They constructed a railroad $7\frac{1}{2}$ miles long which extends from their dock at the outer end of Homer spit back to the mainland where it rises to the top of the bluff about 200 feet above the beach and ends at Coal Creek. A house and store, with over a dozen tool, engine, and storage houses were built at the dock and this group of buildings is known as Homer. Eight or ten buildings constituting the mine camp were erected at the other end of the railroad, and underground work was begun in the fall of 1899 by driving a three-compartment shaft 125 feet. In 1900 tunnel No. 1 was driven in the face of the bluff on a seam of coal $6\frac{1}{2}$ feet thick, but it proved to be very we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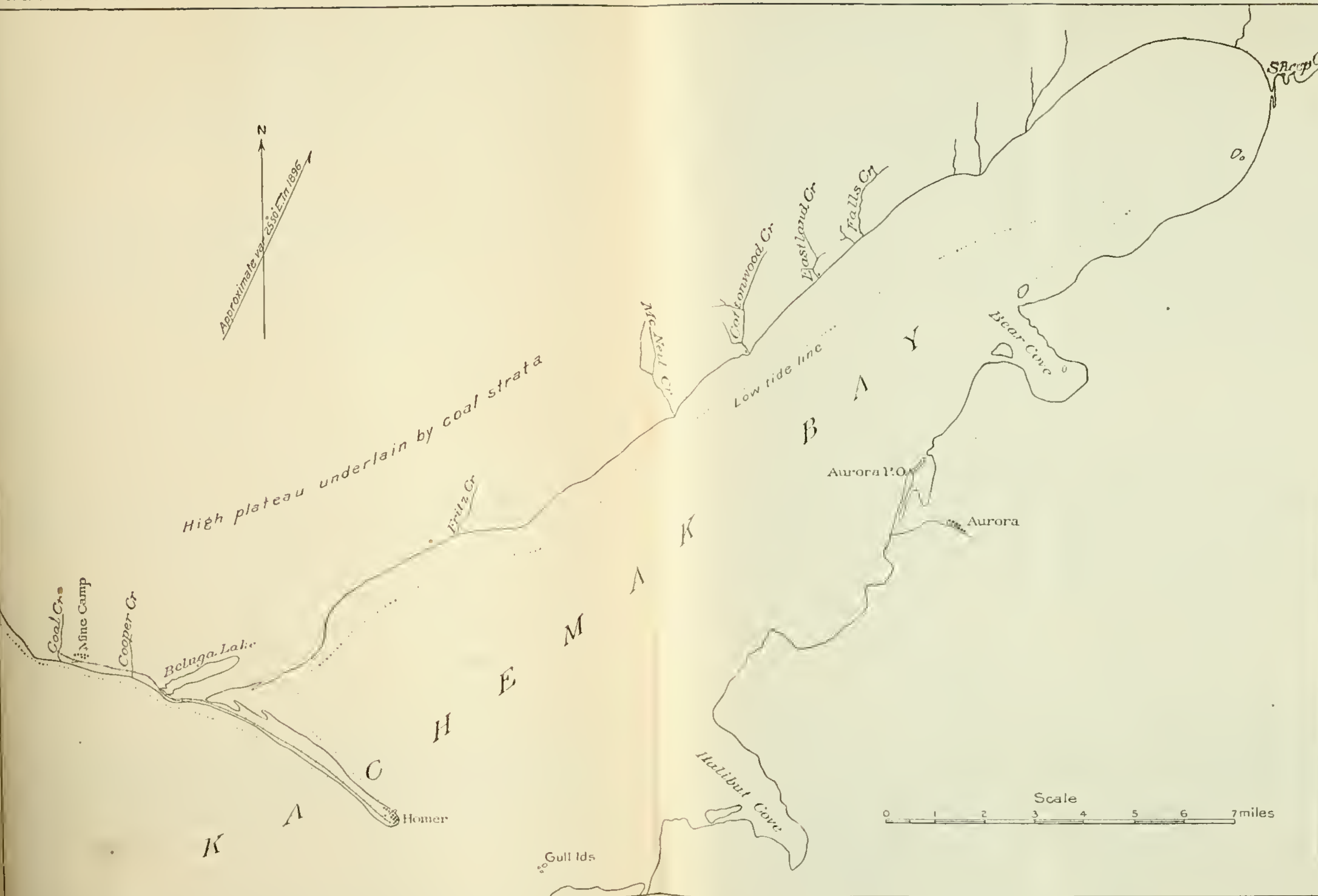

SKETCH MAP OF KACHEMAK BAY, COOK INLET, ALASKA.

and was abandoned. Tunnel No. 2 was driven 350 feet and had to be pumped to keep it dry. Coal was brought to the mouth of the tunnel in mine cars, dumped into a skip, and hoisted up over the bluff by a square framed derrick which spilled into a railroad car standing on the spur. At the west end of the railroad a vertical three-compartment shaft was sunk over 25 feet and a tunnel was started on coal in the sea bluff to connect with the shaft. This third or Ray tunnel was driven 125 feet. All work on this property was discontinued in March, 1902, but the company holds possession by retaining a representative on the ground.

Detailed sections of two seams exposed in the sea bluff near tunnel No. 2, the position of which in the section of the formation given above can be recognized by their total thickness, follow.

The first and thickest seam, which is over 50 feet below the top of the bluff at the hoist, measures thus:

Coal seam at mine camp, Kachemak Bay.

	Ft.	in.
Bony coal and clay	2	0
Clay shale	1	8
Coal	2	6
Clay parting	0	2
Coal	1	1
Total	7	5

Following is the section of the bed on which the tunnels were driven:

Coal seam at mine camp, Kachemak Bay.

	Ft.	in.
Coal	3	0
Clay parting	0	½
Coal	1	11
Clay parting	0	1½
Coal	1	5
Total	6	6

Other seams of coal that lie below those named in the long section above are found below high tide off the point beyond Coal Creek.

The coal in the section at the mine camp is hard, compact, glossy lignite. It is clean, does not smut the hands, and tends to break into cubical fragments when dried.

COAL BEDS EAST OF HOMER SPIT.

The first prominent coal locality inside Homer spit is the Bradley seam, on the beach a short distance southwest of Fritz Creek, a small creek 6 miles northeast of the spit (Pl. III). The outcrop of the Bradley seam runs from the bluff obliquely across the beach with an average northward dip of about 15°. Although this seam aggregates

about 7 feet, there is only 18 inches of clear coal, the greater portion of the bed being made up of thin seams interbedded with leaf-bearing shale. It is said that J. A. Bradley drove a tunnel at this place several years ago, but it is now caved in.

From Fritz Creek eastward to McNeil Canyon the coal seams exposed in the sea bluff are mostly thin and of little value. In one stretch of 2 miles the section is almost entirely sandstone. This soon dips below sea level, giving place to a 100-foot section containing half a dozen coal seams, the thickest of which is 27 inches.

About 10 miles northeast of Homer coal is exposed in the canyon of McNeil Creek. Several years ago a Mr. Curtis drove two short tunnels on a 4-foot seam at a point 400 yards west of the canyon and a few feet above the beach. The seam is called the Curtis seam. A short wharf and coal bins were built and still remain. When the locality was visited in June, 1904, one tunnel was partly closed and full of water; the other, above the bins, was covered by a dirt slide. Iron-stained sandy clay forms the roof, and the floor is gray clay. In the bluff above the Curtis seam there are three other coals, separated by thick beds of clay or soft sandstone. The lowest of the three is nearly 4 feet thick and has only 4 inches of parting. The rocks lie nearly horizontal, so that this seam is found about 300 yards up the canyon, where it causes a small cascade 35 feet above high tide.

A short distance farther up the canyon, and 60 feet above tide, a 20-inch coal seam causes another cascade. From this seam to the top of the bluff the section measures 325 feet, and contains 21 feet 4 inches of coal. Four of the coal seams are 3 or more feet thick. Two hundred tons of coal were mined in McNeil Canyon in 1891, taken to San Francisco, and submitted to a series of tests.[a]

The section on Cottonwood Creek, 2 miles beyond McNeil, consists largely of soft shale. It is reported that prospecting has been done here, but no traces of it were seen. In the canyon no coal seams over 2 feet thick were seen until at an elevation of 300 feet a bed appeared which seemed at a distance to have a thickness of 3 feet. The coal in this canyon is lighter, perhaps less compact, and dull. Some of it preserves its woody structure so perfectly that it will split in slabs and chips like wood.

A heavy sandstone layer conspicuous near the top of the bluff at Cottonwood Creek seems to be almost as high above the beach at Eastland Canyon, 1½ miles farther east. At the mouth of the canyon there are the ruins of three cabins, a short dock, and a small tramway which runs up the gulch 2,000 feet. Active mining exploration work was done here by M. B. Curtis, engineer in charge, from 1894 to 1897. One-half mile up the canyon the creek cascades over a coal seam which has the following section:

[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 831-832.

Section of coal in Eastland Canyon, Kachemak Bay.

	Ft.	in.
Coal	1	3
Clay	0	2
Coal	0	4
Clay and coal	1	3
Coal	2	6
Total	5	6

This seam is about 250 feet above tide, has a sandstone roof and clay floor, and dips north at an angle of 4°. The tunnel driven at the end of the tramway on this coal seam is choked at the mouth and was not accessible. Farther upstream, on the eastern fork, there is a coal seam 3 feet 2 inches thick at an elevation of 360 feet, and a vertical fault crosses the canyon, trending N. 45° W.

The next stream entering the bay by a deep canyon is 1 mile beyond Eastland. A 20-foot fall within a few rods of the beach suggests the name Falls Creek, given to it by the writer. A number of coal seams 1 to 2 feet thick are exposed in the bed of the stream. There are at least four which range in thickness from 3 to 6 feet. The coal in this canyon is fairly solid, but light and woody. It has a dull fracture and brown color, unlike the glossy lignite west of Homer spit. This character is noticeable from McNeil Canyon eastward.

From Falls Creek toward the head of the bay the strata dip at low angles toward the north. For some distance the upper part of the bluff is red, due to the baking of clay beds by the burning of coal seams. The coal-bearing formation is visible as far as the head of the bay, and a 3-foot seam of coal is reported 15 miles beyond the head of the bay, 200 feet above tide, on Sheep Creek.

Shoal water extending a half mile or more offshore makes access to the Kachemak Bay coal seams difficult, and the quality of the fuel is such that there is no large demand for it. Analyses of some of these coals are given on page 170.

The Kachemak Bay coals carry a large quantity of moisture and it seems probable that 15 to 20 per cent is the amount that would be held by the marketed coal. Dall's analyses for the same field average less than 12 per cent moisture, which is explained by the fact that his samples were kept in cloth bags and had a chance to dry. A recent experiment by W. F. Hillebrand showed that a coarse ground sample contained in a covered tin standing in the laboratory lost one-half per cent of moisture in a week.

The fuel ratio of the coal from this bay is low and its bulkiness is also an objection. It can be mined in large quantity without much difficulty and is an excellent house coal, but the demand for it is small in this region. This coal will make steam readily and might be used locally if it were offered for sale at the proper price. If put on the market, Kachemak Bay coal would have to compete with higher grade lignites

from Puget Sound and bituminous coal from Vancouver Island. It could do this successfully in a few Alaska markets if mined on such a large scale as to be sold at a low price, commensurate with its quality.

PORT GRAHAM.

The small bay of Port Graham, on the east side of Cook Inlet, lies halfway between Kachemak Bay and the southern end of Kenai Peninsula. The cove on the north side of Port Graham under Dangerous Cape was called Coal Bay by Portlock, who discovered coal here in 1786.[a]

At the west end of a crescent-shaped beach behind Dangerous Cape is a low bluff, in which are exposed sedimentary rocks lying between igneous rocks 1,000 feet apart. The series is composed of sandstone, shale, clay, and coal. Two outcrops of coal were seen, one on the beach between high-tide and low-tide level and the other near the west end of the gravel beach at high-tide mark. A tunnel driven on the coal at this outcrop is now caved and inaccessible. At the mouth of the tunnel there are between 8 and 9 feet of coal, some of which is good and some bony. On top of the bluff, a short distance back from the beach and about in line with this tunnel, is the mouth of a large shaft. The dump here is small and shows no coal, from which it may be inferred that the shaft ended at no great depth. On the beach at the end of a log crib is the framework of a 6 by 10 foot shaft, in one corner of which are two vertical hollow logs, which may have been pump columns. An old Russian miner, who lived for many years at Seldovia and died there in May, 1904, at the age of about 95 years, said he had worked in this shaft. As he remembered it, the shaft was 180 feet deep and passed through five seams of coal, of which the first was about 5 feet thick, the three succeeding ones smaller, and the fifth, at the bottom of the shaft, was about 9 feet thick.[b] Nothing is known of the extent of the workings in this shaft, although 2,700 tons are said to have been mined.[c] The ruins of several large log buildings on the hill back of the shafts, and of a stone pier extending out at least 100 yards from the mouth of the tunnel on the beach, point to considerable activity in this bay at the time of the Russian occupancy, from 1855 to 1867.

The coal at Port Graham is lignite, black, brilliant, clean to handle, with conchoidal fracture. An analysis is given on page 170.

CAPE DOUGLAS.

Cape Douglas is at the southwestern entrance to Cook Inlet and terminates the prominent shoulder on the northeastern end of Alaska Peninsula. Rumors of the existence of coal in this vicinity led Dall

[a] Portlock, Nathaniel: A Voyage to the Northwest Coast of America, 4°, London, 1789, pp. 102-110.

[b] Information furnished verbally by E. G. Wharf, of Seldovia.

[c] Bancroft, H. H., History of Alaska, p. 694.

to visit the region in 1895,[a] but he found no coal seam of any economic value. The writer was detained at Cape Douglas during the entire month of July, 1904, and had ample opportunity to investigate the geology of the cape and vicinity. The report that coal occurs here was based probably on the appearance of some beds of black shale which outcrop at one or two points in the sea bluff, and at a short distance closely resemble coal seams. The mountains on the mainland back of the cape are composed in part of sedimentary rocks, and show numerous beds which from the coast look like coal. An examination of the talus slopes and stream beds showed only black shale, and the conclusion was drawn that there is no coal seam of any value at Cape Douglas.

AMALIK HARBOR.

As time was limited and progress with the small sloop used as a means of conveyance was slow, it was impossible to examine each bay, and Amalik Harbor was passed by without entering. Dall has the following to say concerning it:[b]

This locality is situated on the south shore of the peninsula, in about latitude 58° 5′. Behind Takli Island there is a good anchorage, well sheltered from all winds. The coal seams are on the main shore opposite the island and close to the entrance. The rocks are chiefly coarse sandstone, resting conformably on an andesitic agglomerate and containing andesitic pebbles. These sandstones have a thickness of 250 feet or more and dip northeast at an angle of about 30°. Low down in the series are strata of stream-bedded, sharp gravel, in layers about 5 feet thick, with three seams of impure coal, each about 18 inches thick. About 4 inches of this is pure glossy coal having a bituminous aspect. Unlike most Alaskan coals, it soils the hands when touched, and is said to be good for use in a blacksmith's forge. * * * The small dimensions of the seam, however, forbid anticipating any commercial future for it, though it may be useful for local purposes.

On the shore about 1 mile southwest of Takli Island there is a low bluff of sedimentary rocks. These are soft sandstone and fine conglomerate, with some shale. They are cut by dikes and sills of greenish, fine-grained andesite and basalt, and are more or less faulted. A seam of coal, exposed for 100 feet in the bluff, with shale roof and floor, was measured by the writer:

Section of coal near Amalik Harbor.

	Ft.	in.
Bony coal	0	6
Clay	0	2
Bony coal	1	8
Coal	0	2
Clay	0	2
Bony coal	0	3

[a] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 798.
[b] Op. cit., p. 799.

	Ft.	in.
Coal	0	3
Clay	0	$0\frac{1}{2}$
Coal	0	$2\frac{1}{2}$
Clay	0	3
Coal	0	10
Bony coal	0	7
Total	5	1

A short distance farther down the beach a bed of carbonaceous material about 8 feet thick is exposed for 25 feet between faults. It is composed largely of bony coal, with a few 2-inch or 3-inch layers of hard, glistening coal. Although the thickness of these seams is several feet, it will be seen readily that because of their small extent and bony character they have no value.

KATMAI.

Katmai Bay is a few miles west of Amalik Harbor, on the south shore of Alaska Peninsula, in latitude 58°. It is reported[a] that coal has been found on one or more of the trails which lead out from Katmai, but this has not yet been confirmed.

COLD BAY.

Rumors of coal at Cold Bay, 30 miles west of Katmai, seem to have little foundation. A careful investigation of the entire shore of the bay showed nothing in the way of coal excepting occasional streaks of bright, glistening carbon contained in Jurassic rocks on the shore. These bands of coal were several feet long and up to 2 inches thick.

UGASHIK LAKE.

Coal is reported on the southeastern side of the southern one of the Ugashik lakes by Mr. Mittendorf, a trader at Nushagak.[b] This lake is 40 miles southwest of Cold Bay and back of Kialagvik Bay. The coal outcrops all over the side of the bluff on the lake. It is poor, resembling cannel coal in appearance, but has a rather high temperature of ignition. A. G. Maddren, collector for the National Museum, believes the deposit here is not lignite, but a mass of peat which has been baked or coked by a lava flow.

KODIAK ISLAND.

Reports from various sources confirm the presence of coal-bearing series in a number of places on this island. It was impossible for the writer to investigate them personally, and the following statements are based on the observations of others.

[a] Tenth Census, Report on Alaska, p. 87.

[b] Spurr, J. E., A reconnaissance in southwestern Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 262.

At three points near the middle of the island on the eastern shore here are sandstones containing thin seams of lignite. These localities .re the shores of Ugak Bay, Eagle Harbor at the native settlement of)rlova, and the northern shore of Kiliuda Bay next southward.[a] It is eported[b] that in a little bight off the entrance of Kiliuda Bay there are wo coal seams, probably 6 to 8 inches thick. On the northern shore f the island coal is found along part of the shores of Uganik Bay and f Uganik Island in the bay, which opens into Shelikof Strait. Coal xists in a clay bank near the beach at Red River, which is a small tream on the south side of Cape Ikolik, the westernmost point of odiak Island.

SITKINAK ISLAND.

Coal occurs on the high island of Sitkinak,[c] one of the Trinity slands, at the southern end of the Kodiak group. In the rocks vhich outcrop boldly in a lagoon on the northeast side of the island here are a number of seams of coal, one of which is said[d] to be 10 or 2 feet thick, standing vertically in a bluff 20 feet high. The deposit s somewhat limited in extent. Small schooners have sometimes visited his locality to get a boat load of coal, which can be obtained handily rom the beach. It makes steam readily, but is inconveniently situ-ted for access by large vessels. The almost constantly raging surf eating around the shallow coast is a serious obstacle.

ANIAKCHAK BAY.

The presence of coal seams in Aniakchak Bay is reported from everal sources. It is understood that there is a seam of coal about 7 nches thick included in a 5-foot bed of carbonaceous shale. This coal s said to be clean, to burn with little flame or smoke, and to leave nly a small amount of ash. Thus it seems to be of good quality.

CHIGNIK BAY.

Chignik Bay is a large reentrant on the south side of Alaska Penin-ula, in longitude 158° and latitude 56° 20′. Coal has been mined onstantly at one locality in the vicinity of this bay for nearly twelve ears and has led to the search for other prospects. It is now known o occur in four places in this region: Chignik River, Whalers Creek, hompson Creek, and Hook Bay.

The Alaska Packers' Association salmon cannery, near the mouth f the lagoon at the head of Chignik Bay, requires about 600 tons of oal a year for use in its towing steamer and several launches and for he machinery of the works, and for a number of years the fuel has een supplied from the mine on Chignik River.

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[a] Dall, loc. cit., p. 800.
[b] Information from P. W. Francis, of Seattle, Wash.
[c] Eleventh Census, Report on Alaska, 1893, p. 78.
[d] Information from P. W. Francis, of Seattle, Wash.

CHIGNIK RIVER.

The coal mine on Chignik River, which was hastily examined, is on the west bank, well up toward the mouth of the first lake, and about two hours distant, by steamer, from the Alaska Packers' Association cannery. The channels of the lagoon and river are so shallow that a boat drawing over 2 feet of water can not make the passage on less than half tide. The seam outcrops directly on the river bluff, comes to the surface of the ground in a ravine above the bluff, and has been traced inland more than half a mile. It was discovered in 1885,[a] but it was not until 1893 that the company began to develop the mine.

The bed dips northeast at an angle of 20° and strikes N. 5° W. Two 6-foot tunnels have been driven on the seam, about 40 feet apart. The upper tunnel is about 250 feet long and has been widened to a width of 40 feet in the clear in some places, with a single crosscut to the lower tunnel. It is now abandoned, and work is being done only in the lower tunnel, which runs in nearly straight for 500 feet. At the face the tunnel strikes a roll in the floor which cuts out the greater part of the seam. Rooms have been opened on the upper side of the tunnel up to the roll, which runs diagonal to the direction of the tunnel, so that in the first room, which is about 150 feet from the entrance, the roll is 75 yards from the drift. The coal is carried from the breast of the rooms to the tunnel in chutes and taken out in tram cars, from which it is dumped directly on the barge.

A section of the seam measured in the tunnel is as follows:

Section of Chignik River coal seam.

	Ft.	in.
Dry bone, with thin coal streaks	0	3 to 9
Coal	0	6
Coal and dirt	0	8
Coal	1	0
Bony coal (gob)	1	5
Coal	1	4
Total	5	2

The roof of the seam, which is shale with thin streaks of coal, is very even and is overlain by sandstone. The floor, however, is not so regular, and a roll or swelling in it reduces the thickness of the seam at the end of the tunnel from 5 feet to 9 inches. It is possible that the roll, which is known to be rather long, may be narrow, and that a short tunnel driven through it would discover the full thickness of the seam on the other side. An analysis of this coal is given on page 170.

The coal is solid and bright, and comes out in good-sized chunks. When used under a boiler it has to be stoked very frequently to keep it burning fast, and the engineer at the cannery reported to Dall that

[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 802.

118 pounds of Chignik coal equal 100 pounds of Wellington (B. C.) coal. Properly handled it is a fairly satisfactory steaming coal, although it makes a large amount of ash, and fires have to be cleaned much oftener than with Wellington coal.

Chignik River mine is worked throughout the year by two men without machinery, the coal being undercut by hand and shot down.

WHALERS CREEK.

Whalers Creek is a small stream that enters the lagoon from the north a short distance below the mouth of Chignik River. Coal is exposed for 600 feet along the northernmost of the three main branches of the creek.

The strike in this ravine is N. 35° E., and the dip is east at an angle of 21°. The section of the coal seam is as follows:

Section of coal on Whalers Creek.

	Ft.	in
Coal	1	0
Clay	0	1
Coal	0	8
Clay and bone	0	1
Coal	1	7
Bone	0	0½
Coal	1	0½
Bone and coal	0	7
Total	5	1

In appearance the coal is a lignite much the same as that mined at Chignik River, but the section of the bed is better, the partings being thin. A short prospect tunnel has been driven on the outcrop, but the property is rendered of little value by a series of faults which have broken the rocks into blocks. A fault about 500 feet below the tunnel and another 115 feet above it cut the coal out entirely. On the upstream side, about 40 feet above the tunnel, a vertical fault trending N. 45° W. throws the coal down 6 feet.

Half a mile south of this coal prospect a bed of fossil invertebrates was found in the ravine of the middle fork of Whalers Creek. T. W. Stanton reports them to be Upper Cretaceous. This locality lies between the coal on Whalers Creek and Chignik River, but its relation to the coal-bearing formation was not determined.

THOMPSON CREEK.

In the valley of Thompson Creek, which enters the head of Chignik Bay and is about 7 miles north-northwest from Chignik, there are several seams of coal. The only information available concerning the region is furnished by Chas. J. Brun, of Chignik, who states that there are three seams, of which the top one is 5 feet thick. About

60 feet below it is a seam showing 4 feet of clean coal, and again 40 feet lower is another seam about 3½ feet thick. Thompson Creek coal has the same appearance as that of Chignik River, being a fair grade of lignite.

HOOK BAY.

A curved recess on the north shore of Chignik Bay, about 12 miles northeast from Chignik, is known as Hook Bay. Coal is reported about 4 miles from the beach, on the right-hand fork of a stream which enters the bay. According to C. J. Brun, who is familiar with the locality, there are two seams of coal 5 and 6 feet thick separated by 2 feet of bony shale. He claims that this coal is superior to the others at Chignik Bay. It is free burning and makes yellow ash. The beds strike north and dip east at an angle of about 15°. The writer had no opportunity to visit the locality.

OTHER LOCALITIES.

Coal was seen at two other localities on Chignik Bay. Near the native village that stands 1 mile east of the Alaska Packers' Association cannery, a tunnel was driven several years ago about 20 feet on what appeared to be a 4-foot seam of coal. It proved to be alternate 4-inch layers of coal and dirt, and the work of mining being unprofitable it was abandoned.

At the head of the creek which enters Anchorage Bay near the old Hume cannery, there are carbonaceous shales in abundance, and one block of clear, bright coal, 6 inches thick was found. The bed from which it came appeared to pinch out into carbonaceous shale within a few yards.

HERENDEEN BAY.

Circumstances made it impossible to investigate the Herendeen Bay coal field during the summer of 1904, and the following statements were obtained by personal interviews with people who are familiar with the region.

Herendeen Bay is a branch of Port Moller, which is situated on the north side of Alaska Peninsula (opposite Shumagin Islands). It is reached from Portage Bay, on the southern side of the peninsula, by a trail about 9 miles long. An area 20 square miles in extent on the cape between Port Moller and Herendeen Bay is supposed to be underlain by coal, but the real extent may be much less.

Several companies[a] have tried to develop the coal in this field, but without success, because the coal seam is cut off by faults, and its continuation could not be found. The latest attempt was in the summer of 1903. The drift previously begun on a seam 4 feet thick was driven 200 feet farther by a new company, making the face 250 feet

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[a] Dall, op. cit., p. 805.

from the mouth. About 125 feet from the mouth an entry was driven 75 feet long up the dip and a raise made from it to the surface, a distance of 30 feet. A level on the coal, run from this entry about 25 feet from the main drift, struck a fault at 15 feet. Believing that there was another bed of coal about 26 feet below the one being worked, a tunnel was started near the mouth of the entry and run in level against the rise for 108 feet. Several 10-inch to 15-inch seams were encountered, but none larger. The mine is over a mile from the sea and about 300 feet above tide. In April, 1904, the miners stopped work and seized the property for unpaid wages. A considerable quantity of lumber, rails, tools, hardware, etc., landed at Portage Bay, was never taken to the mine.[a]

Judging from the analysis given on page 170, this coal is bituminous in character.

It is reported that gas was encountered in such quantity in the mines as to make the use of safety lamps necessary.

UNGA ISLAND.

While the writer was at Chignik, G. C. Martin went to Unga to see the Apollo mine. He made notes on the lignite at Zachary Bay, Unga Island, and has written the report which follows:

Unga is the principal island of the Shumagin group which extends about 50 miles south and east from Portage Bay, Alaska Peninsula. The group lies half way between Kodiak and Unalaska islands. The eastern Shumagins, according to Dall, are granite, those in the middle of the group are largely composed of metamorphic quartzites and schistose rocks,[b] while Unga contains volcanic rocks and Tertiary beds. It has been known for many years that these Tertiary strata contain coal seams.

The lignite of Unga Island is apparently restricted in area to the peninsula on the west side of Zachary Bay, or Coal Harbor, as it is more commonly called, a region about 6 or 8 square miles in extent. It occurs in the soft shale and sandstone of the Kenai formation, of Oligocene age. The Kenai formation is overlain by the Unga conglomerates, which are of Miocene age. These Tertiary rocks dip northwest at various angles, reaching in places 20°. They are adjoined on the south by crystalline rocks, principally andesites. The crystalline rocks may underlie the Tertiary sediments or may be intruded into them, or the contact may be one of faulting.

The following section, which was measured on the west shore of the bay near Mr. Tibbey's coal mine, shows the character of the Unga conglomerates and of that part of the Kenai formation which is above sea level.

Section on west shore of Coal Harbor.

	Ft.	in.
1. Conglomerate and sandstone	140	0
2. Shale and sandstone	20	0
3. Conglomerate of fine pebbles	68	0
4. Conglomerate of coarse pebbles	2	0
5. Sandy shale	1	0

[a] Information concerning the work done by this company was obtained verbally from a miner who was employed at Herendeen Bay from February to April, 1904.

[b] Dall, op. cit., p. 807.

	Ft.	in.
6. Coal	6	6
7. Shale	12	0
8. Shale, with 4 thin coal seams	15	8
9. Shale and sandstone	50	0
10. Coal	1	11
11. Shale and sandstone	64	0
12. Shale, with 3 thin coal seams	6	6
13. Sandstone and shale	15	0
14. Shale and sandstone, with 2 thin coal seams	10	4
15. Sandstone	26	0
16. Shale, with numerous thin coal seams	25	0
17. Sandstone and concealed	45	0
18. Concealed to tide level	62	0
Total	570	11

The beds represented by Nos. 1 to 4 represent the Unga conglomerate and have been determined by Dall to be of Miocene age. The remaining strata belong in the Kenai formation and, according to Dall, are of Oligocene age.

The most promising of the seams is No. 6 of the above section, which has in detail the following section:

Section of coal seam on west shore of Coal Harbor.

	Inches.
Coal	2
Shale	1
Coal	12½
Sandy shale	4 to 7
Coal	17
Shale	½ to 2
Coal	6
Bone	2½
Shale	6
Coal	2
Shale	1
Coal	1
Shale	8 to 9
Coal (thickness reported)	12+
Total	76 to 82

The upper part of this seam contains over 3 feet of coal of fair quality, in which the partings are not thick enough to interfere seriously with mining. The coal is a bright, clean lignite of sufficient firmness to stand handling without excessive crushing.

A group of thin seams of no economic importance is represented in No. 8. No. 10, a seam consisting of 23 inches of clean coal without partings, may prove to be workable. A tunnel which opened up this seam some years ago has now caved in. Another group of thin unimportant seams similar to No. 8 is represented in No. 12.

Only two seams known at present may be regarded as possibly of economic importance. These are lignites of fair quality, which compare not unfavorably with much coal that is sold on the Pacific coast.

If the coal is mined with sufficient care to keep it clean and a local market is secured, it would seem that it should be able to compete with the somewhat better but more expensive coals that are now being shipped to this part of Alaska.

SOUTH COAST FROM CHIGNIK BAY TO END OF PENINSULA.

Other points on the peninsula where coal occurs in small amount are Coal Cape, near Mitrofania Island, west longitude 159°; Portage Bay, 160° 35′; Beaver or Otter Bay and Coal Bay, 161° 40′, west of Shumagin Islands. Nothing is known of the coal at these localities, but it is assumed to be of the same character as that found farther east along the peninsula; it occurs probably in thin seams.

ALEUTIAN ISLANDS.

The chain of islands that extends westward from Alaska Peninsula is composed largely of volcanic material but contains some sedimentary and metamorphic rocks. Lignite-bearing beds are supposed to occur on several of the islands, the supposition being drawn inferentially from reports of localities where amber has been found. The only island on which coal is said to exist[a] is Akun, which is on the south side of Unimak Pass. It is probable that thin seams of lignite of limited extent may be found in the Aleutian Islands, but as far as present information goes it is doubtful whether any of them may be commercially valuable.

ANALYSES.

In the following table proximate analyses of coal from most of the fields in southwestern Alaska are given. These were all made in the chemical laboratory of the U. S. Geological Survey, with the exception of the analysis of Matanuska coal made by C. C. Bogardus, of Seattle, Wash. The samples from Kachemak Bay, Port Graham, and Chignik River were collected by the writer. Each sample represents the commercially valuable portion of a seam. These samples were washed and dried several hours in the open air before crushing and quartering, and sealed in tin cans, so there was little chance for evaporation during the six months which elapsed before they were analyzed. Two sets of analyses were made, one from samples ground in a coffeemill, and the other ground to powder in an agate mortar. The analyses of the coarse-ground samples are believed to represent more closely the condition of the coal as it would be mined and marketed, and are given below. Five analyses, made by George Steiger, are from samples collected by W. H. Dall in 1895. They were "taken from the seam and tied in bags of stout duck, and analyzed immediately on arrival at headquarters"[b] several months later.

[a] Dall, op. cit., p. 811.

[b] Dall, op. cit., p. 827.

Analyses of coals from southwest Alaska.

Sample No.	Locality.	Moisture.	Vol. comb. matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.	Analyst.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
	Matanuska River	1.15	22.50	69.34	6.42	0.89	3.08	C. C. Bogardus.
3	Kachemak Bay, mine camp	20.87	40.71	33.29	5.13	.36	.81	W. T. Schaller.
4	Kachemak Bay, mine camp	19.26	43.95	28.74	8.05	.32	.63	Do.
7	Kachemak Bay, mine camp	19.22	41.22	31.96	7.60	.38	.77	Do.
8	Kachemak Bay, Curtis seam	18.92	37.62	28.59	14.87	.46	.76	Do.
9	Kachemak Bay, McNeil Canyon.	21.54	39.10	30.26	9.10	.34	.75	Do.
10	Kachemak Bay, Eastland Canyon.	19.29	40.31	33.11	7.29	.27	.82	Do.
1	Port Graham	16.87	37.48	39.12	6.53	.39	1.04	Do.
	Amalik Harbor	1.62	36.56	52.92	8.90	.75	1.45	Geo. Steiger.
	Kodiak Id., Red River	12.31	51.48	33.80	2.41	.17	.66	Do.
	Chignik River	2.72	39.92	43.76	13.60	2.15	1.12	W. T. Schaller.
	Herendeen Bay	3.43	39.00	47.40	10.17	.44	1.21	Geo. Steiger.
	Unga, upper seam	11.26	40.51	41.24	6.99	2.17	1.02	Do.
	Unga, lower seam	10.58	66.21	15.26	7.95	.56	.23	Do.

Sample 3 in the above table was taken from the outcrop of the 2-foot 9-inch seam near the west end of the Cook Inlet Coal Fields Company Railroad, Kachemak Bay; sample 4 came from 50 feet inside tunnel No. 3 at the mine camp; sample 7 represents 30 inches of a 4½-foot bed occurring below tide about 500 feet off shore near Coal Creek; sample 8 was cut from the outcrop of the Curtis seam 400 yards west of McNeil Canyon; sample 9 is from a 4-foot seam found 300 yards from the beach up McNeil Canyon; sample 10 is from the lower 30-inch bench of a 5½-foot coal seam, on which a tunnel was driven in Eastland Canyon, and sample 1 was taken from the outcrop below tide at Port Graham.

These analyses show that the Matanuska coal is by far the best obtained at any of the localities described, but the writer does not know how representative it is of the seam or field. The field is 50 miles from tide water and several hundred miles from any present source of demand, and, seemingly, can hardly compete as a steam coal in outside markets with the semianthracite and bituminous coal which has been found at Controller Bay, but may find special markets if it proves adaptable for smelter use.

In the next table are given averages of analyses of Kachemak Bay and Unga coals in comparison with competing coals from Vancouver Island and Puget Sound:

Averages of analyses of Pacific coast and Alaska coals.

Number of analyses.	Locality.	Moisture.	Vol. comb. matter.	Fixed carbon.	Ash.	Sulphur.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
6	Kachemak Bay[a]	19.85	40.48	30.99	8.67	0.35
2	Unga Island[b]	10.92	53.36	28.25	7.47	1.36
5	Controller Bay[c]	2.18	12.76	74.33	10.73	.93
5	Comox,[d] Vancouver Island	1.25	26.87	58.74	11.76	1.38
4	Nanaimo,[d] Vancouver Island	2.10	34.68	54.47	8.09	.66
10	Washington[e]	4.43	31.60	56.01	7.45	....
17	Coos Bay,[f g] Oregon	10.22	44.19	38.91	7.35	.90

[a] W. T. Schaller, above, p. 170.
[b] Dall, Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 828.
[c] Martin, G. C., Bering River coal fields: Bull. U. S. Geol. Survey No. 225, p. 374.
[d] Annual Report of Minister of Mines, 1902, British Columbia, p. H 262.
[e] Smith, Coal fields of the Pacific coast: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, p. 490.
[f] Ibid., p. 510.
[g] Diller, Geology of northwest Oregon: Seventeenth Ann. Rept., U. S. Geol. Survey, pt. 1, p. 504.

MARKET.

The present market for coal in southwestern Alaska is largely at Valdez, Seward, Dutch Harbor, and the salmon canneries along Alaska Peninsula, on Kodiak Island, and in Bristol Bay. Most of the canneries use Wellington (British Columbia) coal brought from the States as ballast in their own ships. It costs them about $5 a ton at Seattle and $7 at San Francisco. A large market supplying fuel for steamers may be developed at Valdez and Dutch Harbor in the future. Passenger steamers and revenue cutters get Wellington coal at these points for $12 a ton. The completion of the Alaska Central Railroad would make Seward a large town, with increasing demand for fuel, and, if the Matanuska River coal proves abundant and desirable, might make Seward a coaling station for ocean vessels.

In view of the very high grade of the coal which has been found at Controller Bay and which may soon be in competition with the Pacific coast bituminous coals, it hardly seems possible that any of the southwestern Alaska lignites have a bright future, unless there should be a local demand for their use in gas engines, for which there is some reason to believe they are adapted. The development of an extensive copper mining and smelting industry in Prince William Sound, which may be looked for at some future date, will afford another market for fuel, but the demand will be for a coking coal. It seems possible that the Matanuska coal will meet this requirement.

COAL FIELDS OF THE CAPE LISBURNE REGION.[a]

By Arthur J. Collier.

INTRODUCTION.

Cape Lisburne is a bold headland which marks the northwestern extremity of a great land mass which projects into the Arctic Ocean from the western coast of Alaska between latitudes 68° and 69°. It is 160 miles north of the Arctic Circle and 300 miles in a direct line from Nome, and is the only point north of Bering Straits where hills above 1,000 feet in height approach the sea. This peninsula can be conveniently termed the Cape Lisburne region. In outline it roughly resembles a hand, of which Cape Lisburne forms the knuckle and Point Hope, about 40 miles southwest of Cape Lisburne, the index finger, pointing west. The Point Hope Peninsula is a triangular area about 11 miles wide at its base, next the main land, that extends 16 miles out to sea. It consists of two low sandspits which converge and meet near the point, the space between being occupied in part by a lagoon called Marryat Inlet and in part by the delta of the Kukpuk River. It is therefore a typical cuspate foreland. East of the Point Hope foreland there is a range of hills called the Lisburne Mountains, which extend from Cape Lisburne southward to Cape Thompson, and at their highest point probably attain an elevation of 2,500 feet.

East of the Lisburne Range there is a region of rolling hills and ridges, usually below 800 feet in elevation, which extends eastward for an undetermined distance. The trend of the ridges and many of the valleys is dependent on the bed-rock structures.

The drainage of the region is effected mainly by one large river, called the Kukpuk, whose basin occupies most of the interior portion. It rises about 60 miles southeast of Cape Lisburne and discharges into Marryat Inlet. Thetis Creek and Pitmegea River are two smaller streams which drain a region lying north of the Kukpuk basin and discharge into the Arctic Ocean 33 and 40 miles, respectively, east of Cape Lisburne.

[a] Abstract of bulletin in preparation.

A settlement at Point Hope, including a mission and several whaling stations, contains about 250 Eskimos and 20 white men, all of whom are dependent on the fisheries or the fur trade. The mineral resources of the region, which are as yet undeveloped, consist of the coal deposits to be described.

These coal fields are accessible only by sea from July to October, inclusive. There is no harbor or protection for sea-going vessels, but in calm weather, or when the winds are from the south, coal can be boated or lightered to ships anchored from ½ to 2 miles off shore.

The nearest protected harbor is Kotzebue Sound, about 200 miles southeast, near which there are several gold-mining camps of considerable importance. The whole region is exceedingly bleak and dreary. It is far beyond the northern limit of spruce timber and even the willows are stunted, the largest seen in the most sheltered places being not over 4 feet high. The nearest standing timber suitable for mining purposes is at the mouth of the Noatak, 150 miles southeast.

HISTORY AND EXPLORATION.

Captain Cook discovered and named the cape in the year 1778, but coal was first reported in the region by Mr. A. Collie, who accompanied Captain Beechey to the Arctic Ocean in 1826 and 1827. The point of discovery by Mr. Collie was near Cape Beaufort, an unimportant feature of the coast line 70 miles east of Cape Lisburne. Messrs. Belcher and Collie, of the Beechey expedition, also collected paleontological materials and made notes on the geology at Cape Lisburne and Cape Thompson.

During the last twenty-five years whalemen have often replenished their fuel supply from these coal beds, the points most frequently visited being Corwin Bluff, 28 miles east of Cape Lisburne, where the U. S. revenue cutter *Corwin*, Captain Hooper commanding, took on 20 tons of coal in 1881, and the Thetis mine, 36 miles east of Cape Lisburne, where the revenue cutter *Thetis* coaled in 1888 and 1889.

The discovery of gold at Nome in 1898 drew attention to these deposits as possible sources of fuel for the mines of Seward Peninsula, and several companies were organized to exploit them. Large areas of coal land were staked and several cargoes of coal, probably in all more than 1,000 tons, were mined and sold at Nome in 1900 and 1901, since which time the production has been merely nominal.

Schrader,[a] of the United States Geological Survey, visited Corwin Bluff in 1901 at the end of his field season in northern Alaska and collected notes on the geology of the region from various prospectors.

On account of the economic importance of the coal deposits and the scientific interest in the geologic formations, a more detailed

[a] Schrader, F. C., A reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 109–114.

examination of the field was undertaken by the United States Geological Survey in 1904. The party for this purpose was landed at Corwin Bluff on July 23, and after examining the coast line from Cape Beaufort to Point Hope sailed from the latter point on August 22. The party consisted of the writer, who was in charge, Chester Washburne and C. J. Hutchinson, field assistants, and Joseph Edge, boatman, all of whom rendered untiring and efficient service and contributed in a greater or less degree to the fund of information obtained.

The important economic result of this expedition is the demonstration (1) that the coal fields are much more extensive than has generally been supposed, and (2) that there are two distinct coal-bearing formations in the region. One of these formations lies east of Cape Lisburne and contains low-grade bituminous coal of Mesozoic age; the other lies south of the cape and contains high-grade bituminous coal of Paleozoic age.

GEOLOGY.

The hard rock formations of this region fall readily into two groups, the Paleozoic and the Mesozoic, whose distribution is indicated by the topographic features, since the Paleozoic rocks produce the high relief of the Lisburne Range, while the Mesozoic rocks underlie the undulating lowlands northeast of these mountains.

PALEOZOIC FORMATIONS.

Heavy calcareous sandstones and interbedded slates which occur on the west side of the Lisburne Mountains constitute what is probably the oldest formation of the region. They are exposed in sea cliffs over a stretch of about 15 miles north of Marryat Inlet. The sandstone beds range in thickness from 1 to 10 feet, while the slates are usually thinner. Their total thickness has not been determined, though it is certainly not less than 1,000 feet. The structure consists of a series of broad, open folds, the dips rarely exceeding 30°. Being massive beds, the strains to which they have been subjected have been taken up in two sets of well-defined joint plains and a slaty cleavage in the softer members. The sandstones often present schistose phases and contain secondary mica. This formation is Paleozoic, probably pre-Carboniferous in age, but no fossils have been found in it.

The sandstone is conformably overlain by a series of slates, shales, cherts, and limestones of Carboniferous age, a part of which has been called the Lisburne formation.[a]

These rocks form the sea cliffs from Cape Dyer to a point 3 miles east of Cape Lisburne (a distance of about 20 miles), the greater part

[a] Schrader, F. C., A reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, pp. 62-67.

[o]f the cliffs at Cape Thompson, and the main mass of the Lisburne [M]ountains. The series consists of divers beds which fall into three [g]roups: (1) A lower group consisting of slates, shales, and limestones, [c]ontaining several coal beds and yielding Paleozoic fossil plants; (2) a [m]edian group of black cherts, slates, shales, and cherty limestones con[t]aining marine bivalve fossils, the most common being an aviculopec[t]en; (3) an upper group of massive limestones of great thickness, [m]ade up largely of coral, and seeming to shade off into massive white [c]herts.

The shaly members are often closely crumpled, while the more [m]assive beds present broad, open folds complicated by frequent thrust [f]aults, making the stratigraphy difficult to decipher. The prevailing [s]tructures, indicated by strikes and fault planes, seem to extend south[e]astward nearly parallel to the trend of the Lisburne Range. The [t]otal thickness of the coal-bearing member is not very great, probably [n]ot exceeding a few hundred feet, though data for a satisfactory esti[m]ate of thickness are wanting on account of the intense crumpling to [w]hich the beds have been subjected. Fossil plants of a type common [i]n the Paleozoic coal beds of the eastern United States have been [f]ound in the black slates associated with the coal.

MESOZOIC FORMATIONS.

The relation of the Paleozoic to the Mesozoic rocks could not be [d]etermined, for, at the contact, faulting has brought older beds above [t]he younger.

The Mesozoic rocks occur on the coast about 3 miles east of Cape [L]isburne and extend beyond the limits of the area covered by this [i]nvestigation. They consist of two members, of which the older is [c]oal-bearing while the younger is not only destitute of coal but also [o]f fossils.

The coal-bearing member, which has been called the Corwin forma[t]ion, begins on the coast line about 26 miles east of Cape Lisburne and [a]bout 2 miles west of Corwin Bluff. From this point it extends [e]astward to and beyond Cape Beaufort, the eastern limit of the area [c]omprised in this investigation. This formation consists of rather [t]hin-bedded shales, sandstones, and conglomerates. The shales, which [f]orm the greater part of the section, vary from greenish-brown calca[r]eous to black carbonaceous beds, and in texture from mud stones to [f]ine-grained sandy shales.

The sandstones occur at infrequent intervals through the forma[t]ion, in beds usually less than 10 feet in thickness. Their outcrops [f]orm low ridges, which are easily traceable over eroded areas. The con[g]lomerates are made up mainly of quartz and chert pebbles, ranging in [d]iameter from one-half to 4 inches. A conglomerate bed about 15 feet [t]hick, which reaches the coast at Corwin Bluff, makes a distinct ridge

from 100 to 200 feet high, which has been traced southeastward for about 15 miles, giving a definite key to the stratigraphy of a portion of the field.

The thickness of the Corwin formation exposed along the coast near Corwin Bluff is not less than 15,000 feet. The base of the formation has not been observed, but it probably rests unconformably on the Paleozoic rocks.

Fossil plants collected from it indicate that the age is Jurassic.

The structure consists of several broad synclines and anticlines, the dips of the beds varying from 0° to 60°. There is no evidence of faulting other than minor shearing movements parallel with the bedding planes.

The Corwin formation is conformably overlain by a more arenaceous series of sandstones and shales in which neither coal beds nor fossils have been found. The contact of these rocks with the Corwin rocks may be seen about 2 miles west of Corwin Bluff, whence it extends southeastward for several miles to the limit of the area investigated. The western limit of the formation is a well-defined fault line extending southeastward from a point on the coast 3 miles east of Cape Lisburne, where the formation is in contact with the Paleozoic, which is overthrust. The structure of this formation increases in complexity from its base at the top of the Corwin formation as this fault is approached; there are intense crumpling and numerous minor thrust faults. For this reason it is impossible to estimate the thickness of the formation, but the evidence obtained indicates that its minimum thickness is not less than 5,000 feet.

QUATERNARY FORMATIONS.

Pleistocene and Recent deposits of gravel, sand, silt, and ground ice occur at a number of places in the region, the largest area being about 88 square miles in the Point Hope foreland, already described. A part of this area is said to be underlain by ground ice.

Smaller Quaternary deposits occur near the mouth of Thetis Creek, at Cape Sabine, at Cape Beaufort, and in the valley of the Pitmegea River.

Where such deposits occur along the coast, cliffs are formed by the undercutting of the surf, in which ground ice is often exposed beneath beds of peat, silt, or talus from the higher hills.

DETAILED DESCRIPTION OF THE COAL FIELDS.

MESOZOIC COAL FIELD.

Geology, topography, and extent.—The Mesozoic coal-bearing formation, described on page 175, outcrops along the coast from a point 26 miles east of Cape Lisburne eastward for 40 miles to Cape Beaufort, beyond which point the hills recede from the coast. The formation

probably continues northeastward for an undetermined distance, since it is known to occur at Wainwright Inlet, 120 miles beyond Cape Beaufort, where it contains coal seams and has yielded fossils. Throughout this distance coal fragments are found on the beach, where they have been pushed up by the ice, and pieces of coal have also been dredged up from the sea floor. Similar coals are reported to occur at the headwaters of the Colville and Ikpikpuk (Chipp) rivers, 300 miles east of Cape Lisburne.

The southern boundary of the coal-bearing formation runs southeastward from the coast for about 10 miles, beyond which point it probably turns southward. Coal is reported in the interior 20 miles south of Cape Beaufort, so that it is safe to say that the area of coal land in the Lisburne region is not less than 300 square miles, and is probably very much more than that.

The topography of this field consists of low rounded hills and ridges, usually less than 600 feet in elevation. The ridges and drainage are determined by the bed rock structure.

Investigations the past season indicate that there are not less than 40 coal beds in the formation, aggregating about 150 feet of coal, and the croppings of many other beds have probably been overlooked. The coal beds, however, are undeveloped, and exact measurements were in most cases impossible. Coal has been mined from a group of beds at Corwin Bluff and from another at Thetis mine, and croppings of coal have also been observed at many other places, the first discoveries being near Cape Beaufort.

Corwin group.—Corwin Bluff, a sea cliff 200 feet high, is about 28 miles east of Cape Lisburne. The highest part of the bluff rises sheer from the water, but about half a mile west of it there are narrow rocky beaches along the foot of the cliff, and a few hundred yards east there is a short sand beach at the mouth of a small creek. The bluff is at the seaward end of a ridge formed by the cropping of the conglomerate bed which has been already noted as giving a definite key to the stratigraphy. The coal beds of the Corwin group are near this bluff and stratigraphically lie both above and below the conglomerate. They strike N. 75° W., and dip SW. from 30° to 40°.

The highest coal seam noted in the series outcrops in the sea cliff $1\frac{3}{8}$ miles west of Corwin Bluff. It is exposed by a recent rock slide from the cliff and contains $4\frac{1}{2}$ feet of coal without partings. The roof and floor are soft shales or shaly sandstones.

A second seam, which has yielded some coal, is about 1,000 feet lower stratigraphically, the intervening beds being shales, which contain several coal seams either too small or too impure to be of value. This bed outcrops in the sea cliff three-fourths of a mile west of the Corwin Bluff, and is developed by a tunnel about 40 feet long, driven without

timbers. The coal in the face of the tunnel is solid and, though frozen, does not break up greatly on exposure to the air. The seam is 5 feet thick and has two thin clay partings, one 1 foot from floor, the other about the middle of the vein. The roof is shaly sandstone, which stands well without timbers. The floor is hard clay shale. A few feet below this seam there is a second undeveloped seam two or three feet thick.

The next bed of importance is about 500 feet lower stratigraphically, the intervening beds being shales that contain four or five small, unimportant coal seams. This bed is probably the original Corwin vein, and has yielded a considerable amount of coal. It has been developed by a tunnel from the sea cliff and an air shaft from the level surface above the cliff, which is about 75 feet above the sea. In the summer of 1904 the entrance to the tunnel was closed by a great mass of ice, the remnant of snow drifts formed during the preceding winter, and the air shaft was filled with water, so that the workings were inaccessible and the coal bed could not be measured. It is reported to have a total thickness of 16 feet, of which 7 feet is clear coal, with no partings, while the remainder contains several partings and is without value.

Below this bed there are shales for about 1,000 feet above the conglomerate bed that forms Corwin Bluff. In this shale there are eight veins of coal, indicated by croppings, which could not be examined in detail, their exposures in the cliffs being inaccessible. Three of these veins are over 4 feet thick. One of them, which immediately overlies the conglomerate, appears from the sea to be about 30 feet thick and to contain impure coal. Another, said to be about 12 feet thick, and a third 4 feet thick are reported to yield clean coal of good quality.

Immediately below the Corwin Bluff conglomerate and between it and a massive sandstone is an irregular bed, which is reported to have produced about 500 tons of coal during one season. This bed has been affected by shearing movements of the inclosing strata. In other parts of the series the inclosing shales are soft beds which have yielded equally to shearing strains, so that the coal beds have remained unaltered; but in this case, the conglomerate and sandstone beds being rigid, the whole effect of such forces has been felt by the coal bed which lies between them. The coal bed appears in the face of the bluff as a series of lenses. The coal itself shows evidence of shearing but is obtained in large pieces. Since this bed was worked the face of the bluff has fallen down, making the coal inaccessible.

The next bed of importance in the series outcrops in the sea cliff about 1,000 feet east of Corwin Bluff, and is stratigraphically 40 feet below the conglomerate bed, the intervening strata being sandstones and shales containing many plant remains and one small coal bed below the irregular one noted above. The section of the coal bed

from the top down is as follows: Clean coal, 1 foot; black shale, 1 foot; clean coal, 4 feet. The coal from the upper and lower benches is about alike. The roof of this bed is 1½ feet of black shale, and above this lies shaly sandstone. The floor of the bed is black shale 2 feet thick, below which is 1 foot of impure limestone. This bed has been partially opened at the top of the cliff, which is about 100 feet high. It has yielded to whaling ships some coal that is said to have been of good quality. The face of the cliff up to a height of 75 feet above the sea was covered in July and August, 1904, with snow and ice, the remnant of snowdrifts accumulated the winter before.

Thetis group.—The coal beds of the Thetis group outcrop along the coast 6 miles east of Corwin Bluff near a sandstone cliff about 30 feet high, the seaward end of a low ridge which continues inland in a southeast direction. This cliff is about 4½ miles west of Cape Sabine and 2 miles east of the mouth of Thetis Creek. The strike here is N. 60° W. and the dip about 20° toward the southwest. The coal beds are stratigraphically about 8,000 feet below the lowest bed of the Corwin group. The intervening shales and sandstones carry some scattering coal beds, but none that are known to be of economic importance. The coal is reported to have been first worked by a whaleman, who found all the accessible beds at Corwin Bluff already occupied by the crews of other ships and was directed to this place by natives. The U. S. revenue cutter *Thetis* coaled here in 1888. It is reported that when the coal was discovered a large outcrop extended across the beach standing above the sand and that a considerable amount was easily obtained. In 1904 extensive snowdrifts covered the beaches and the cliff face, so that no bed was seen outcropping on the beach.

The original Thetis vein, which was worked in 1888, probably overlies the massive sandstone which forms the cliff noted. Croppings on the level ground above the bluff indicate two coal beds of considerable thickness, with 15 or 20 feet of shale between. Reports of the workings indicate that the vein has a thickness not less than 6 feet. In about 700 feet of dark shales, underlying the sandstone bed, 10 coal beds were noted, only 2 of which are of possible economic value. The first of these is about 250 feet below the Thetis bed and outcrops about 100 feet east of the high sandstone cliff. It contains 4 feet of clean coal without partings. The second is about 200 feet lower in the stratigraphic column and outcrops about 600 feet farther east. It contains 3 feet of clean coal without partings.

Beds below the Thetis group.—Below the beds of the Thetis group there are 3,000 feet of shales and sandstones in which several coal beds have been noted, but none of commercial value.

East of Cape Sabine.—East of Cape Sabine the structure probably causes a repetition of the beds described above, but the work has not been sufficiently detailed to identify them. The coal-bearing forma-

tion is not exposed in the sea cliffs, and the croppings in the interior are not well defined. Croppings of half a dozen or more coal beds were seen south of a camp 10 miles east of Cape Sabine. One of these which was well exposed was found to be over 4 feet thick. The beds strike N. 80° E. and dip north at angles varying from 20° to 40°.

Cape Beaufort field.—The occurrence of coal at Cape Beaufort, 40 miles east of the Corwin Bluff, was noted by Mr. Collie seventy-five years ago. At this point there is a hill 500 feet high, but the cliff is made up of Quaternary gravels, ground ice, and talus from the hill, so that there are no good exposures. In the hasty examination made last summer the croppings of no less than 4 coal beds were discovered on this hill, but no measurable exposures were found. Mr. F. C. Schrader, who visited the locality in 1901, reported seeing a partially developed coal bed 6 feet thick one-eighth mile from the coast. The beds strike south 45° east and dip southwest at an angle of 20°.

Inland extension—The present investigation was necessarily confined to a strip a few miles wide along the coast, but, as has been already pointed out, the inland extension of the coal field can be reasonably inferred from topographic evidence. Residents of the region who have made the trip from Point Hope to Cape Sabine, by way of the Kukpuk and Pitmegea rivers, report finding coal at their camp on the portage between these rivers. This camp could not have been less than 20 miles inland and southeast of Cape Sabine.

Character of Mesozoic coal.—Analyses which have been made of a number of samples of these coals indicate that the coals are noncoking bituminous and scarcely better than lignites.

The average of the analyses of samples taken from six of the beds described is as follows:

Average of six analyses of Mesozoic coals from Cape Lisburne.

[Samples taken by A. J. Collier; analyses by W. T. Schaller.]

Fixed carbon	47.43
Volatile combustible matter	36.95
Moisture	10.79
Ash	5.16
Sulphur	.50
Fuel ratio	1.28

It is reported that these coals have not given complete satisfaction for steaming purposes. Though they burn readily and produce steam quickly, they are of low specific gravity and are not lasting. It takes about double the amount of this coal, as compared with Comax coal, to maintain a given pressure. It burns with little smoke, but produces a large amount of ash and cinder.

Conditions of mining and development.—There are no permanent developments or conveniences of mining at any of the places where coal has been obtained. When the mines were operated by the whal-

ng fleet the ships steamed up and anchored, sending their crews ashore to mine coal. The coal was dug from the croppings wherever it was convenient. Everything black was sacked up and sent on board. In 1900 and 1901 the Arctic Development Company and the Corwin Trading Company attempted to mine a little more systematically, but as the work was largely done by Eskimos and directed by men inexperienced in coal mining it is doubtful if the product was a fair indication of what the mines would produce if properly developed. Since 1900 a few white men remaining at Corwin Bluff have attempted to mine coal during the winter by short tunnels driven in from the face of the sea cliff.

The results have been unsatisfactory, since the sacked coal piled on the cliff was covered by snowdrifts, which turned to ice, making the coal inaccessible when the ships arrived in the summer. The development of the coal beds from some point back of the cliffs would not be difficult, because of their perfect regularity. If they were properly opened, there is no reason why the mines could not be worked all winter. One obstacle to such development is the absence of timber, but by leaving large pillars this difficulty could be partly overcome.

Coal mined and sacked in winter would be available for shipment in summer if piled at places where the snowdrifts do not form. During the summer months only calm days can be used for boating coal off to the ships. Strong north or northeast winds make landings impossible, and strong south winds also make the work difficult. During thity days, from July 22 to August 22, 1094, there were thirteen days on which the surf was too high for landing, and several more when strong south winds would make the use of a line necessary. A limited amount of coal mined here would probably find a ready sale to whaling ships, and a larger amount could be disposed of in the mining camps about Kotzebue Sound.

PALEOZOIC COAL FIELDS.

Location.—The Paleozoic coal-bearing formation outcrops in several small areas along the coast south of Cape Lisburne, on the Kukpuk River, about 15 miles from the coast, and on the coast at Cape Thompson. The inland extensions and outlines of these areas have not been determined, owing to the short time available for studying them. These coal beds were not reported by any of the early explorers, and they have not been worked to any extent by whalemen. They were first recognized as distinct from the Mesozoic coals by A. G. Maddren, who visited one of the localities in 1900.[a] Small amounts of the coal have been tested in galley stoves, and a few tons have been mined for use at the Point Hope Whaling Station, but no large amounts have been mined and no analyses have been made.

[a] Prof. Paper U. S. Geol. Survey No. 20, p. 113.

South of Cape Lisburne.—Four miles[a] south of Cape Lisburne black, coal-bearing shales outcrop for about half a mile in a cliff about 50 feet high, back of a narrow beach. The locality is near the mouth of a large creek, at which vessels have occasionally taken water. On the south side the shales are in contact with massive limestones, which are faulted over them. The outcrop of the formation extends inland in a southeast direction, but its limits have not been determined. The shales are very much crumpled, and the inclosed coal beds are often sheared, so that no continuous bed remains, but the coal occurs in lenticular masses along fault planes. Maddren reports seeing a 4-foot or 5-foot coal bed which outcropped continuously for several hundred yards inland and dipped north at an angle of 60°. Small amounts of coal have been mined from the lenses noted above, and Washburne reports seeing on the ground a pile of coal which was mined and sacked previous to 1904.

Cape Lewis field.—About a mile south of Cape Lewis, which is a promontory nearly 1,000 feet high, 11 miles south of Cape Lisburne, there is a second exposure of coal-bearing shales which outcrop for half a mile in a low cliff back of the beach. These shales carry, in addition to the coal, abundant fossil plants of Paleozoic type. Except in this cliff no outcrops of coal have been observed, though there are occasional croppings of black shale for 3 miles southward to Cape Dyer. The coal-bearing shales are overlain by thin-bedded limestones and black cherts and slates, which are in turn overlain by the massive limestones of Cape Lewis. They appear to rest comformably on the massive sandstone of which Cape Dyer is composed.

The extension of the formation inland has not been determined. From topographic evidence it seems to extend southeastward and to connect with the area of similar rocks exposed south of Cape Dyer. The croppings of three beds of coal occur at a point about 2 miles south of Cape Lewis.

The upper bed strikes N. 75° E. and dips northward at an angle of 40°. It is 4 feet thick, but is considerably crushed and only fine material can be obtained from the croppings. The seam has one small, indistinct parting near the middle. It could not be traced back from the coast on account of a heavy covering of chert and limestone débris. The roof of this bed is a hard, siliceous slate; the underlying beds are black slates. Two smaller beds, which could not be measured, outcrop south of this at intervals of about 50 yards. The coal beds at this point have not been developed and have yielded no coal. Though only one bed of sufficient thickness to mine has been discovered it is probable that a small amount of development would uncover several beds, some of which may be thick enough to work. The structure at this place does not seem greatly complicated.

[a] This description is based on the work of Chester Washburne. The locality was not visited by the writer.

Cape Dyer field.—A third area of these coal-bearing rocks reaches the coast south of Cape Dyer, where the coal beds are exposed in a low cliff which is nearly continuous from Cape Dyer to the high bluff called the Ears, a distance of about 1½ miles.

Cape Dyer is about 16 miles south of Cape Lisburne. Seen from the north it appears as an isolated butte standing out in the sea, the land back of it being much lower. The coal-bearing rocks probably connect across back of the high point with the area above mentioned, south of Cape Lewis.

The coal-bearing rocks consist of black shales and slates interbedded with limestone. At the north end of this exposure they overlie the massive sandstones of Cape Dyer with apparent conformity. At the south end of the exposure the sandstones overlie the shales, the contact relation being a well-defined thrust fault. Where exposed in the sea cliff the shales and interbedded limestones are very much crumpled and often faulted. Coal beds outcrop at several places, but it is impossible to determine their number, since some of them may be repeated. The largest bed seen measures 40 inches and dips southward at an angle of 50°. The coal is more or less crushed and only small pieces can be obtained from the croppings.

Only one of the other beds presented a measurable exposure—a bed 1 foot thick, about three-fourths of a mile south of Cape Dyer. The coal from this bed was obtained in large pieces. Mr. S. J. Marsh reports that in 1900 a schooner on which he was a passenger took about a ton of coal from this place for use in the galley stove. There are no developments and no indications that the coals have been worked. Development will be difficult and mining will be expensive in this area on account of the disturbed condition of the beds.

Kukpuk River.—Coal beds probably of Paleozoic age outcrop on the Kukpuk River, about 15 miles from its mouth. These have not been examined by the writer, though the occurrence of the Paleozoic coal-bearing formation here comes within his observation. Should coal be developed on this river, Marryat Inlet could be used as a shipping point by light-draft boats.

Cape Thompson.—Similar coals have been reported from Cape Thompson, about 40 miles south of Cape Lisburne. The Paleozoic rocks are known to extend to Cape Thompson and, seen from a distance, the cliffs appear to contain slates similar to those of the coal formation, but the locality has not been examined by the writer.

Inland extension of Paleozoic coals.—Nothing is definitely known of the occurrence of the Paleozoic coal-bearing rocks beyond a point 15 miles from the sea on Kukpuk River. From descriptions of Noatak River, given by S. B. McLenigan, it seems possible that the crumpled shaly rocks of this series may be exposed in the canyon of the Noatak, which is probably about 120 miles east of Cape Thompson.

A specimen of cannel coal of good quality was obtained last summer by W. Thompson near the headwaters of the Kivalena River, which flows into the ocean south of Cape Thompson. This may have come from either of the formations described, though the character of the coal would seem to place it with the Mesozoic series.

Cannel coal and bituminous coal have been found on the headwaters of the Ipikpuk and Colville Rivers, 250 miles east of Cape Lisburne.[a] This is probably in an eastern extension of the Corwin series.

Character of the Paleozoic coals.—The Paleozoic coals are bituminous and of a much better grade than the Mesozoic of the region. The average of the analyses of samples from three localities is as follows:

Average analysis of three Paleozoic coals from Alaska.

Fixed carbon	77.68
Volatile combustible matter	16.82
Moisture	2.74
Ash	2.95
Fuel ratio	4.60

One assay gives sulphur 0.96 per cent. None of the coals coke. In a galley stove they have been found to give a more intense fire than Nanaimo coal. They are probably of as good quality as the average semibituminous coals of the Eastern States. Their occurrence is of special interest, since they are the only coals of Paleozoic age known west of the Rocky Mountains in America.

Conditions of development.—The development of these coals will be difficult on account of the crumpled condition of the beds, but the product will probably command as good a price as the best coals shipped to Alaska.

SUMMARY.

The coals of the Lisburne region are of two distinct classes: Low-grade bituminous coal of Mesozoic age, and high-grade bituminous or semibituminous coal of Paleozoic age.

The Mesozoic coals are known to cover an area of about 300 square miles, but reports obtained from prospectors and others indicate that their extent may be much greater. The coal-bearing formation is of great thickness and contains at least 150 feet of coal distributed in 40 to 50 seams, no less than 10 of which seem to be of economic importance. The geologic structure of the formation is simple and well adapted to mining, to which the greatest obstacle will be the absence of timber in the region. The coal is low-grade bituminous, slightly better than lignite.

During the past 25 years vessels of the whaling fleet and revenue cutters have occasionally obtained a supply of coal from the croppings of the seams in the sea cliffs, and in 1900 and 1901 over 1,000 tons

[a] Schrader, F. C. (with notes by W. J. Peters), A reconnaissance in northern Alaska in 1901: Prof. Paper, U. S. Geol. Survey No. 20, p. 109.

[w]ere mined and sold at Nome for from $18 to $25 a ton in competition [w]ith Washington and British Columbia coals. The coal obtained has [n]ot given satisfaction as compared with coals from Washington and [B]ritish Columbia. While it produces steam rapidly it is not lasting [a]nd leaves too large a percentage of clinker and ash. These defects are [p]erhaps partially remediable by better mining methods. A limited [a]mount of coal from Corwin Bluff, if its delivery could be relied on, [w]ould find ready sale to whalemen and vessels of the Revenue-Cutter [S]ervice at not less than $10 a ton delivered on the beach. At the [p]resent time these coals can not compete at Nome with the outside [c]oals, but in the mining camps of the northern portion of Seward [P]eninsula outside coal rarely sells for less than $30 a ton, and probably [a]bout 1,000 tons of this coal could be easily disposed of each year. Should future development of Alaska or of the commercial activities [o]f the world create such a demand for coal of this character as to [j]ustify the building of a railroad to the region the supply of coal will [p]robably be found sufficient for many years' demands.

The Paleozoic coals are also undeveloped. They occur in limited [a]reas and the beds are very much crumpled and broken, so that mining will be difficult and expensive. The largest beds seen are less than 5 feet thick. On the other hand the coal, a semibituminous of good [q]uality, will compare favorably as a heat producer with any coal used [o]n the Pacific coast, and will probably be suitable for many such special purposes as blacksmithing and metallurgy. The anchorage for vessels near these deposits is protected from northeast gales and partially protected from south winds also, so that the coal can be more easily lightered than that at the Corwin bluffs. Marryat Inlet, which could be reached by a short railroad from the coal fields, affords a good harbor for schooners drawing not over 10 feet, where permanent docks and coal bunkers can be easily maintained.

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O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 259.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified in the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This bulletin is the fifty-second in Series A, the complete list of which follows. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.)

SERIES A, ECONOMIC GEOLOGY.

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Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

APRIL, 1905.

GEOLOGICAL SURVEY PUBLICATIONS ON ALASKA.

Chronologic List of Papers on Alaska.

1891.

Russell, I. C. Account of an expedition to the Yukon Valley in 1889. In Eleventh Ann. Rept., pt. 1, 1891, pp. 57–58. Extract from Professor Russell's complete report in Bull. Geol. Soc. America, vol. 1, 1890, pp. 99–162. (Out of stock.)

——— Account of an expedition to the vicinity of Mount St. Elias in 1890. In Twelfth Ann. Rept., pt. 1, 1891, pp. 59–61. A full report of this expedition was published in Nat. Geog. Mag., vol. 3, 1892, pp. 53–203. (Out of stock.)

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Dall, W. H., and Harris, G. D. Summary of knowledge of Neocene geology of Alaska. In correlation Papers—Neocene: Bull. No. 84, 1892, pp. 232–268.

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Russell, I. C. Second expedition to Mount St. Elias in 1891. In Thirteenth Ann. Rept., pt. 2, 1893, pp. 1–91. (Out of stock.)

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Dall, W. H. Report on coal and lignite of Alaska In Seventeenth Ann. Rept., pt. 1, 1896, pp. 763–906. (Out of stock.)

Reid, H. F. Glacier Bay and its glaciers. In Sixteenth Ann. Rept., pt. 1, 1896, pp. 415–461. (Out of stock.)

Walcott, C. D., *Director*. Account of an investigation of the gold and coal deposits of southern Alaska. In Seventeenth Ann. Rept., pt. 1, 1896, pp. 56–59.

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Map of Alaska, showing known gold-bearing rocks, with descriptive text containing sketches of the geography, geology, and gold deposits and routes to the gold fields. Prepared in accordance with Public Resolution No. 3 of the Fifty-fifth Congress, second session, approved January 20, 1898. Printed in the engraving and printing division of the United States Geological Survey, Washington, D. C., 1898. 44 pp., 1 map. A special publication. The data were brought together by S. F. Emmons, aided by W. H. Dall and F. C. Schrader. (Out of stock.)

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Brooks, A. H. A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers. In Twenty-first Ann. Rept., pt. 2, 1900, pp. 331–391.

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Eldridge, G. H. A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898. In Twentieth Ann. Rept., pt. 7, 1900, pp. 1–29.

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AKER, MARCUS. Geographic dictionary of Alaska. Bull. No. 187, 1902, pp. 1–446. (Out of stock.)

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PENCER, A. C. The Juneau gold belt, Alaska. In Bull. No. 225, 1904, pp. 28–42.

VRIGHT, C. W. The Porcupine placer mining district, Alaska. In Bull. No. 225, 1904, pp. 60–63.

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'RINDLE, L. M. The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska. Bull. No. 251, 1905, pp. 1–89.

'URINGTON, C. W. Methods and cost of gravel and placer mining in Alaska. Bull. No. 263.

PAPERS ON ALASKA IN PREPARATION.

BROOKS, A. H. An exploration in the Mount McKinley region.

COLLIER, A. J. Placer mines of Seward Peninsula.

—— Coal field of Cape Lisburne.

IARTIN, G. C. The geology of Alaska Peninsula.

MOFFIT, F. H. The Cook Inlet gold placers.
PRINDLE, L. M., and HESS, F. L. The gold placers of the Rampart region.
SCHRADER, F. C. The geology of upper Copper and Tanana rivers.
STONE, R. W. The Kachemak Bay coal fields.
SPENCER, A. C. The Juneau gold belt.
WRIGHT, C. W. The mineral resources of Admiralty Island.

TOPOGRAPHIC MAPS OF ALASKA.

The following maps are on sale at 5 cents a copy, or $2 a hundred:

BARNARD, E. C. Fortymile quandrangle; scale, 1:250000.
PETERS, W. J. Juneau special quadrangle; scale, 1:63500.

The following maps are included as illustrations of published reports, but have not been issued separately. They can be obtained only by securing the report:

BARNARD, E. C. Cape Nome and adjacent gold fields; scale, 1:250000. Contained in a special publication of the U. S. Geol. Survey, entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," Washington, Government Printing Office, 1901.
BROOKS, A. H. York and Kugruk regions, sketch maps of. Contained in "A reconnaissance in Cape Nome and Norton Bay regions, Alaska, 1900."
GERDINE, T. G. Koyukuk and Chandlar rivers, portions of; scale, 1:625000. Contained in "Preliminary report of a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899." Twenty-first Ann. Rept., pt. 2, 1900.
——— Seward Peninsula, northwestern part of; scale, 1:250000. Contained in Professional Paper No. 2.
——— Fairbanks and Birch Creek districts, reconnaissance maps of; scale, 1:250000. Contained in "The gold placers of Fortymile, Birch Creek, and Fairbanks districts." Bulletin No. 251.
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Author.

Brooks, Alfred H[ulse] 1871–

. . . Report on progress of investigations of mineral resources of Alaska in 1904, by Alfred H. Brooks and others. Washington, Gov't print. off., 1905.

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